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COMING MEETINGS

Midwinter Convention, New York, N. Y., February 9-13

MEETINGS OF OTHER SOCIETIES

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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A Notable Development in Electric Transactions

The announcement last month of a new type of electric locomotive to be furnished for use on the single phase lines of the New York and New Haven road by the General Electric Co. is significant in that it suggests a means whereby the long-standing controversy between the advocates of alternating current traction and those of direct-current traction may unite upon a solution which combines the advantages and eliminates the disadvantages of both systems.

The new locomotives, of which there will be five for freight service and two for switching service, contain a traveling substation and will be equipped with a synchronous motor-generator set for converting the 11,000-volt 25-cycle single-phase supply to direct current, and with direct current railway motors driving the axles.

Power is collected by the usual pantograph trolley and is delivered to a main transformer situated in the locomotive cab. This main transformer steps down the trolley potential to 2300 volts, which drives a single-phase synchronous motor direct connected to the main generator. The main generator which delivers current to the traction motors is designed with a variable field and the speed of the locomotive is regulated by field control of this generator. The traction motors are of the standard series direct-current railway type, the performance of which is well known. They are geared to the axle through cushion type gears which allow a small movement of the gear ring about the gear hub or center, thus minimizing shocks and stresses in the gears and pinions.

Between the pantograph trolley and the main transformer a time limit automatic oil circuit breaker is installed. Between the direct-current generator and the motors there are a high-speed circuit breaker and line switches. The high-speed circuit breaker will afford protection to both the motors and the generators and will ordinarily prevent the opening of the time limit switch or of the trolley or feeder sectionalizing switches and will thus prevent any interference with the continuous operation of the motor generator set.

The system of control, by varying the field strength of the generator used, in connection with the characteristics of the motor generator set, gives a locomotive which is extremely flexible and adaptable to all operating conditions. It also has the very desirable characteristic of operating at a power factor of unity or better under all ranges of load. The set has been made of sufficient capacity to take care of the rated loads and will also furnish an appreciable amount of reactive current, especially at light loads for power factor correction. This tends to improve the trolley voltage for all load conditions. The locomotives are also so designed that they will operate in multiple unit with the present single-phase locomotives.

The idea of the motor-generator locomotive is an old one and it possesses many attractive possibilities, but before the advent of the high-voltage direct-current motor the weight of the necessary apparatus was found to be prohibitive and for this reason development along the present lines was heretofore impracticable.

Economy requires that the transmission and distribution of current for railway lines be on the alternating system, and the direct-current traction motor is unquestionably cheaper to build than any other type. The combination of these features also offers to the railroads an interchangeable unit that can be transferred from one electrically equipped road to another, similarly to steam locomotives.

Street Cars and Busses

At a recently held Street Railway Convention a visiting railway official remarked that judging from the character of the exhibits one might well conclude that he was in attendance at an automobile show. The manufacturers of buses and bus accessories displayed no end of industry in placing before the visiting railway officials a wide variety of their wares, while electric railway track service equipment was little in evidence. One visitor offered the view that the trolley cars were all busy hauling passengers and that the manufacturers of electric railway equipment were too busy filling orders to have time for the convention.

There has been in some quarters a disposition to view with alarm the competition of buses, but there are certain factors having a bearing upon the trend which it is well to keep in mind.

The continuous increase in population and the increase in the number of privately operated automobiles are rapidly creating a situation where available street way is inadequate for the safe and rapid movement of vehicles. The possibility of providing greater road space is hedged about with many obstacles. The growth of traffic in the streets and at intersections, to an alarming extent is increasing the number of accidents to pedestrians and to passengers in auto cars.

There is something fundamentally right about a passenger transit system which employs tracks, and operates cars of liberal dimensions and sturdy construction, such as electric street cars may be.

Pedestrians have much less difficulty in avoiding cars that run on tracks, the location of which may be seen—cars which cannot dodge about on the street—than in keeping clear of free-moving vehicles which flit from side to side like the proverbial flea.

Of course, for feeder routes leading into main highways the bus is performing a much needed service, but on the main highways where passenger travel is heavy, and on which private automobile traffic is dense, the electric car on rails provides the most logical method of transport from the standpoints of safety, comfort and speed.

Customer Ownership of Utilities

The idea of customer ownership of public service corporations is recognized to have many engaging possibilities. It is agreed that the desired end is best served when the corporation's stock is widely distributed among the users of service, rather than when large blocks of stock are held by a few individuals.

The fact that many corporations have met with very considerable success in attracting investors from among their customers is creditable not only to the efforts along this line put forth by individual corporations, but also to a disposition on the part of the public to respond to such gestures.

It would seem that the success so far attained would suggest that perhaps some further steps are practicable which would serve further to make common the interests of company and customer.

Too often in these undertakings the only effort made by the company is to sell stock. Once a fair share of the stock is so distributed nothing more is done to follow up the initial advantage thus gained. True, as a rule the customer receives quarterly a check in payment of his dividend, but so does the ordinary investor. The customer-owner, and the investor who may not be a customer, each receives the same sort of check; there is no distinction; nothing to indicate to the customer-owner that he is other than an ordinary investor.

Would it not be a logical second step if the customer-owner were to receive a check on special, colored paper, bearing brief mention in a printed line at the top: "Customer owner's dividend check"?

The customer-owner's monthly bill from the compnya for service might also be on bill-heads of the same color, and also carry a similar printed line at the top.

The special dividend check would be a periodical reminder of the partnership, and the notation on the monthly bill might be expected to bring about prompt payment of bills.

Further, large numbers of customers have on deposit with the companies amounts of five dollars or more as a guarantee of payment of monthly bills. When a customer becomes a stockholder (full paid, of one or more shares) would this not present an excellent opportunity for the company to write a suitable letter signalizing a recognition of the cooperative spirit, and a return of the amount of the deposit?

Some Leaders of the A. I. E. E.

Edwin James Houston, the ninth president of the Institute, was born on July 9, 1847, at Alexandria, Virginia. He was educated at the Central High School, Philadelphia, Pa., at which school he was later, and for many years, professor of physical geography and natural philosophy.

About the year 1879, Professor Houston became directly interested in the then new art of electric lighting. Collaborating with Prof. Elihu Thomson he made important contributions to the art, including a complete system of series-arc lighting, brought out in the year 1881 as the Thomson-Houston System. The system was widely used for many years thereafter.

The dynamo introduced as a unit of the lighting system comprised various new and novel features, one of which was an air blast to extinguish sparks occurring between brushes and commutator.

In the year 1884 Professor Houston was appointed by the United States Government a member of the United States Electrical Commission which convened at Philadelphia. He was, by the Franklin Institute, appointed chief engineer of the International Electrical Exposition. He was at that time one of the foremost American scientists, being engaged in many researches and investigations.

He was president of the A. I. E. E. during the terms 1893-4-5. In the year 1895 he resigned from the Central High School, Philadelphia, and became associated with Prof. A. E. Kennelly as a consulting engineer in Philadelphia, continuing in this work until the time of his death, March 1, 1914.

Prof. Houston was author, or joint-author of more than fifty published books. He had conferred upon him the honorary degree of Ph. D. by Princeton University, and during his active years was a working member of practically all of the important American physical and scientific societies.

The Midwinter Convention Papers

The Meetings and Papers Committee has its work in hand unusually well in advance this year, and already some of the papers for the Midwinter Convention next February have been passed upon for early publication. The new rule of the committee requiring manuscripts to be submitted ninety days in advance of the meeting is being rigidly adhered to, and this fixes November 9th as the final date for the receipt of Convention papers.

The High-Voltage Wattmeter

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Review of the Subject.—*A complete laboratory set-up for measuring losses at low power factors from high-voltage circuits is assembled around a moving water column resistance multiplier which permits the direct use of standard low-voltage instruments. A shielding system is used to eliminate capacitance effects in the loading and voltage circuits. The paper contains structural details of the wattmeter aggregation and the loss loading equipment, and the operating procedure for conducting atmospheric and insulator loss measurements.*

* * * * *

Introduction

THE standard dynamometer-type low-voltage volt- and wattmeters may have their voltage ranges ordinarily extended to 1000 volts or thereabouts, by means of resistance multipliers. Higher voltage ranges are feasible only when the requisite multiplying resistances are constructed so as to be free from inductance and capacitance effects. Though expensive, this practise has been occasionally employed for voltages as high as 50,000.

The study of some of the problems encountered in 220,000-volt power transmission projects has required the use of voltage and power meters on extra high voltage circuits, accurate at low power factors. To provide satisfactory instruments for this class of research work, Professor Harris J. Ryan proposed to the authors to abandon the traditional use of "low loss" current control resistances in the voltage circuits and to substitute therefor moving water column resistances. The water columns are inexpensive, quickly erected, free of appreciable inductance and may conveniently be shielded from capacitance effects. When such resistances are designed to limit the currents in the voltage circuits of the instruments to 50 milliamperes at the highest voltages to be used in the studies, ordinary low-voltage standard makes of dynamometer-type voltage and power meters may be used. However, the experimental resources in these undertakings must include the requisite large amounts of power which must thus, necessarily, be consumed by such use of these measuring instruments on high voltage circuits. For example, the voltage circuit of a single instrument as herein presented will require 100 milliamperes, 50 for the instrument proper and 50 for the necessary shield to be considered later. The power thus consumed in a 350,000-volt circuit for the voltage circuit of a single instrument will amount to 35 kilowatts. In some of the application trials of the wattmeter reported upon herein, the low power-factor loading currents were less than 50 milliamperes. To increase the sensitiveness of the wattmeter, the loading current was passed through the moving coil and the voltage circuit current which was doubled (consuming 70 kilowatts) was passed through the field coil. Even so, such cost of power is small when compared with the total of the remaining costs involved in making studies of this character.

Plan

The wattmeter circuits are shielded in such a manner that all appreciable electric fields terminate upon the enveloping shields rather than upon the instruments and the connections. Fig. 1 is a schematic diagram of the shielded wattmeter. The power supply from the high-

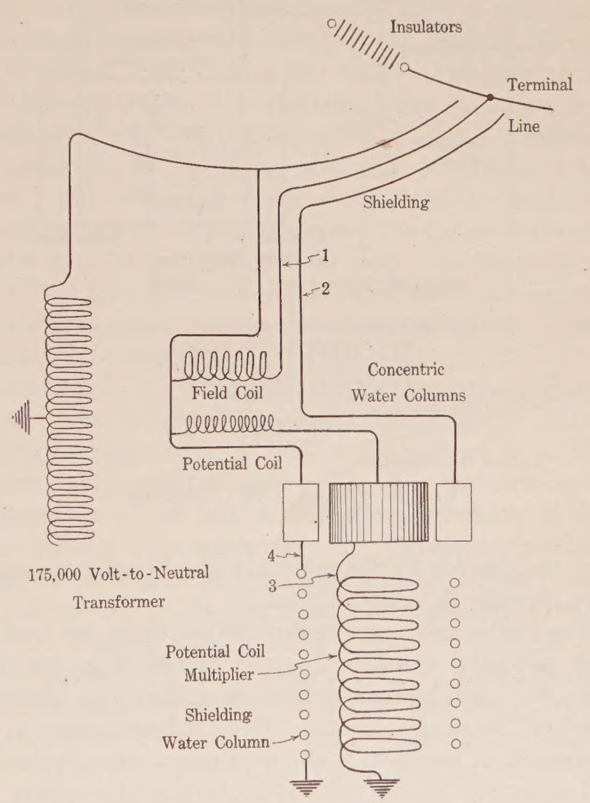

Fig. 1—Schematic Diagram

voltage source is divided into four circuits, (1) the power circuit which supplies power through the instruments to the line, (2) the main shielding circuit which surrounds the power circuit and supplies all losses and electric fields which would otherwise occur therefrom, (3) the potential circuit which contains the water resistance multiplier and (4) the multiplier shielding circuit.

Fig. 2 is a connection diagram of the assembly of

Presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17, 1924.

instruments and auxiliaries which constitutes the high-voltage wattmeter. The source of high voltage is a single-phase testing transformer which has the mid-point of the secondary grounded. A voltmeter, V_m, connected across the voltage winding of the transformer permits an accurate determination of the secondary r. m. s. voltage. A terminal which facilitates the connection of the wattmeter to different experimental lines permits a direct connection of the power circuit to the line and insulates the end of the shielding circuit

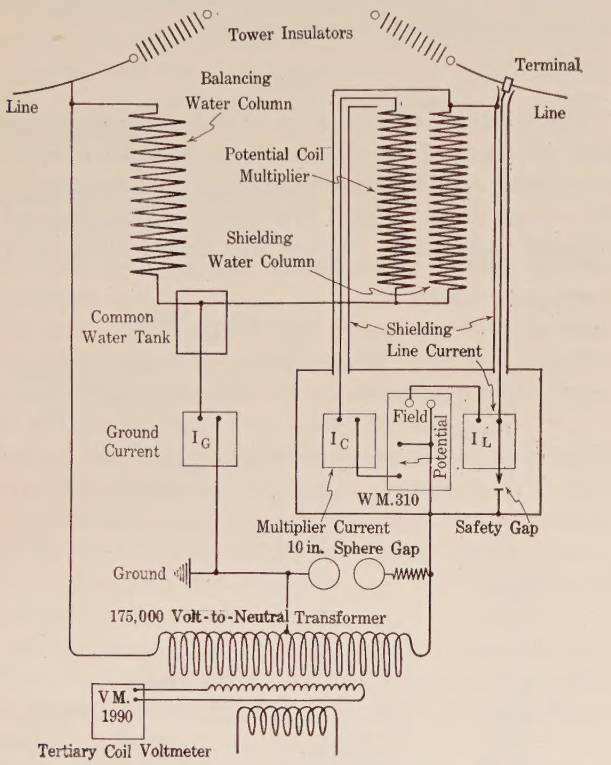

FIG. 2—CONNECTION DIAGRAM

from the line for a voltage that is equal to the resistance drop through the instruments.

The indicating instruments which must be used at high potential consist of a wattmeter, W_m, and two milliammeters located in the shielding cage which is insulated from the ground. One milliammeter, I_L, is connected in series with the field coil of the wattmeter and measures the current flowing through the power circuit to the line. The other milliammeter, I_C, is connected between the potential coil of the wattmeter and its multiplier and measures the current in the potential circuit. Because the resistance of the water column in the wattmeter voltage circuit changes with temperature, its value must be determined for each set of observations from the readings of instruments I_C and V_m. The multiplier is shielded by a concentric water column, the lower end of which is connected to the low-potential terminal of the multiplier. A balancing water column is necessary to load the other side of the transformer and avoid errors due to phase displacement. The low potential terminal of this balancing water column and the low potential terminal of the multiplier are joined and grounded through a milliammeter, I_G. A zero ground current indicates that the loads to neutral on the transformer are in balance. A sphere gap voltmeter provides a means for determining the crest values of the voltages to neutral.

Voltage Circuit Resistance Multiplier

The multiplier is shown in the center of the illustration, Fig. 3. It is connected in series with the potential circuit of the wattmeter and consists of a water column contained in 71.5 ft. of ½-in. rubber hose. A cylindrical galvanized sheet iron tank, 20 in. deep and 19 in. in diameter, serves as a reservoir of sufficient capacity to supply the multiplier column with water continuously for half an hour. The water column which serves as a shield for the multiplier column is contained in 78.5 ft. of ½-in. hose. The reservoir which supplies water to this column is an annular galvanized sheet iron tank,

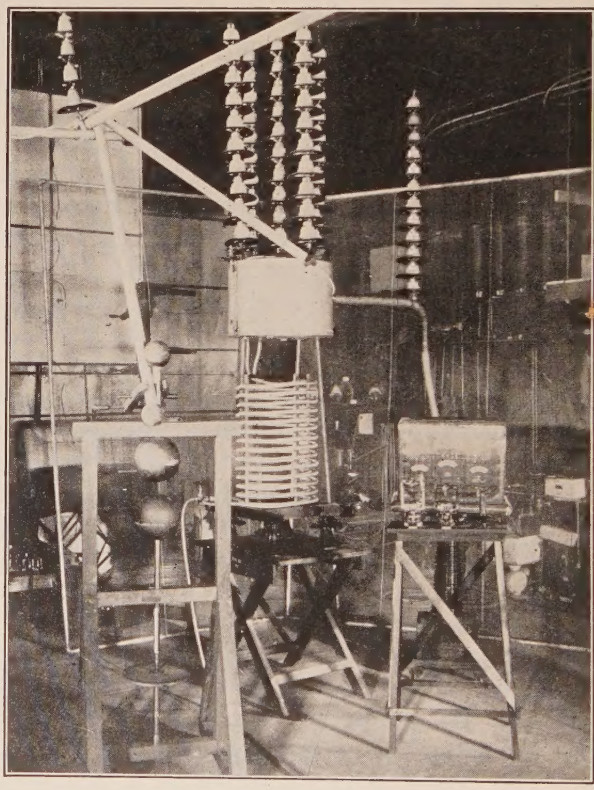

FIG. 3

19 in. deep, 21 in. inside diameter and 29.5 in. outside diameter. Four wood seperators maintain the tanks in their relative concentric positions. A glass gage on the side of the shielding tank indicates the level of the water supply.

For effectiveness in shielding and economy of space the hose water columns are formed into two concentric coils with the shielding coil on the outside. The coils are 36 in. high and are mounted vertically on four 1-inch by 1-inch upright bakelite rods 39 in. long which

are placed at quadrant points on a 20-in. circular center line between the coils. Each coil forms a 14-turn helix with a $2\frac{1}{2}$-in. pitch. The helices are fastened to the bakelite strips by small cotton cords which pass through holes in the bakelite. The maximum radial potential difference between corresponding points on the helices is that due to the drop of potential through the instruments. Since this drop is small, no special precaution is necessary in insulating the helices from each other. The axial potential difference between adjacent turns on the helices is 12,500 volts when the line voltage is 175,000 volts to ground. The voltage gradient is 6250 volts per inch, which gives a reasonable factor of safety, assuming the flash-over voltage of air to be 10,000 volts per inch.

Dowel pins are used in the construction of the multiplier frame in fastening wood spreaders to the upper ends of the bakelite rods as metallic pins would be possible sources of corona formation. The tops of the hose columns are connected to taps in the bottoms of their respective reservoirs by means of standard hose couplings. The lower ends of the water columns are joined so that they discharge through a common globe valve. The rods supporting the water columns are fastened to a wood base which rests upon four pin-type insulators. The annular reservoir is supported by four ten-unit insulator strings, while the inner reservoir is supported by a single ten-unit insulator string. Turnbuckles permit the proper distribution of the load between the insulator strings.

The resistance which provides the balancing load on the transformer is a water column contained in 75 ft. of $\frac{3}{4}$-in. rubber hose. This water column has approximately the same resistance as that of the multiplier and its shield in parallel. The column itself is connected to a 30-gallon galvanized iron tank which is suspended from a ten-unit insulator string. A glass gage on the side of the tank indicates the level of the water. The flow of water is controlled by a valve at the lower end of the column. A flexible 2-in. conductor connects the top of the column electrically to the transformer bus.

The water discharged from the columns flows into a common discharge tank insulated from the ground. Wire connections provide paths of low resistance from the low potential terminals of the water columns to the discharge tank.

The dimensions of the water columns are those which proved satisfactory for the tap water available at Stanford University. This water has an approximate resistivity of 1400 ohms per centimeter cube at 15 deg. cent.

Indicating Instruments

The instrument shield consists of a platform and a cage mounted on a 30-in. porcelain pedestal which provides sufficient insulation for a working voltage of 175,000 volts to ground. The platform is a 22-in. by 30-in. board clamped to the upper end of the pedestal. Wooden cylinders are grooved to fit flush with the top of the board so that the edges of the platform have a two-in. radius of curvature. The platform is covered with copper fly screen.

The cage consists of a wood frame 33 in. high, 30 in. long and 22 in. deep, covered with copper fly screen. The frame is doweled and glued together and the screen is fastened with brass tacks. All corners of the cage have a two in. radius of curvature to limit corona formation. The leads from the instruments pass through a brass plate screwed to the back of the cage. Brass hinges hold the cage to the platform and allow the cage to be raised in order that connections and adjustments may be made to the instruments.

A standard dynamometer-type low-voltage wattmeter, when used as the instrument in the high-voltage wattmeter, functions as a calibrated electro-power-dynamometer. A variable multiplying factor must be introduced to determine watts from the readings of the wattmeter aggregation. The power dynamometer used in the high-voltage wattmeter when employed for corona loss studies was designed to have a full scale deflection at 20 per cent power factor. The maximum voltage ranges were 75 and 150 volts. The maximum current ranges were (1), with the fields in series, 0.5 ampere, and (2), with the fields in parallel, 1. ampere. The scale had fifteen large divisions subdivided into tenths. This instrument was not sufficiently sensitive for accurate results when the power loss to be measured was less than 50 watts at 350,000 volts. In the present state of the art a more sensitive instrument may be had from the manufacturers for use when small power losses are under investigation.

The current, I_c, in the wattmeter potential circuit, and the line current, I_L, were measured by milliammeters which have full scale deflections of 75 milliamperes. The ground current, I_G, was measured by a milliammeter which had a full scale deflection of 15 milliamperes. The voltmeter, V_m, for measuring the voltage coil voltage had a maximum range of 450 volts. The instruments in the line circuit were protected from surges by a safety gap mounted within the instrument cage as shown in Fig. 2. A wire spring connected to the line conductor and a copper plate connected to the shield when separated by a sheet of tissue paper formed such gap. The breaking down of this tissue paper would short circuit the line current ammeter and the current coils of the wattmeter. Three telescopes, mounted on a suitable stand several feet in front of the instruments as shown in Fig. 3, were used in reading instruments I_c, I_L, and W_m. When the telescopes were focused on the meters within the cage, the screen did not interfere with the observer's vision, provided sufficient distance was allowed between the instruments and the screen.

The source of variable high voltages used for the corona loss integrity trials was a 150-kv-a. transformer with a maximum voltage rating of 350,000 volts. A voltage testing coil which gives a faithful 1/1000 reproduction of the secondary voltage is strategically located

in the windings of the transformer. The testing coil voltage in volts is equal to the secondary voltage in kilovolts. A 2300:230-volt multi-tap transformer serves as a primary supply for the high-voltage transformer. A hand-operated induction regulator provides uniform variation throughout the 23-volt interval from one tap to another of the multi-tap transformer.

The sphere gap crest voltmeter as shown in the foreground of Fig. 3 was an essential unit in the assembly of the high-voltage wattmeter for the measurement of atmospheric losses. The 10-in. spheres were mounted according to the specification given by Farnsworth and Fortescue[1]. The calibration curve used for this sphere gap was based on data given for 250 millimeter spheres with one sphere grounded in Table 204 of the A. I. E. E. Standards for 1922. A 300,000-ohm protective resistance was connected in series with the sphere gap to limit the current at spark-over.

Structural Details of Atmospheric Loss Loading Equipment

Fig. 4 is an illustration of the general assembly of the

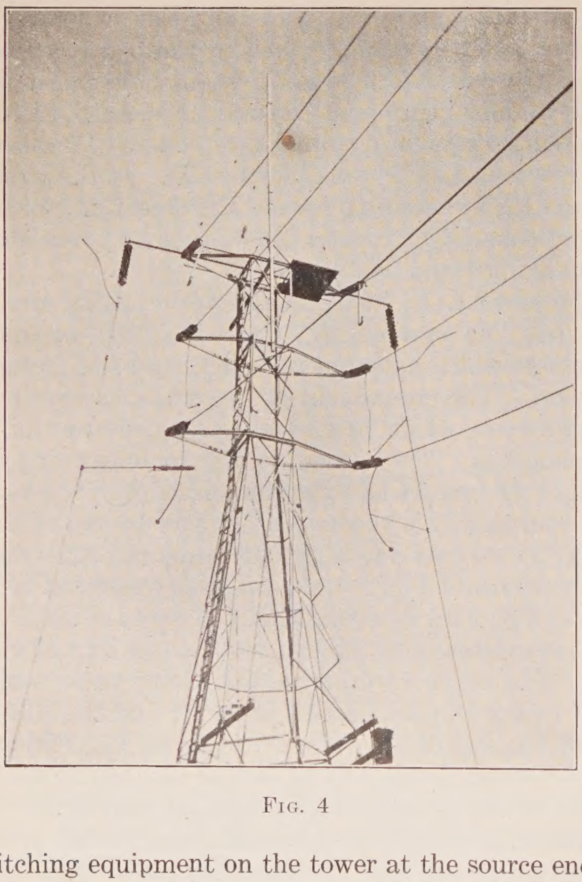

Fig. 4

switching equipment on the tower at the source end of the experimental line. Each length of cable is dead-ended to the tower cross-arms by a ten-unit string of 10-in. cap and pin-type suspension insulators. The vertical distributing busses which supply power to the transmission cables are insulated from the top of the source tower and from the ground by ten-unit insulator strings. These busses are equipped with projecting arms to facilitate the interchange of connections between the busses and the cables. Each bus is pivoted so that it may be rotated in either direction until the desired connection is made from the projecting arm to the corresponding conductor of the single-phase line under test.

Fig. 5 illustrates the high-voltage terminal projecting from the vertical distributing bus. The line conductor is connected to this terminal by means of a 6-ft. hook-

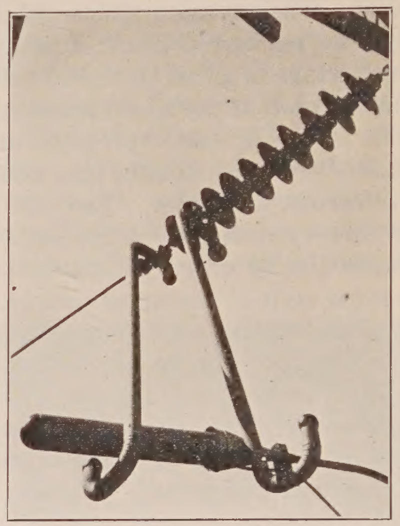

Fig. 5

link of 2½-in. galvanized sheet iron tubing. The main part of the terminal consists of a cylinder of galvanized sheet iron, length 30-in., diameter 5-in., one end terminating in a hemisphere of thin copper. The cylinder is mounted and insulated (1) from the hollow shaft of the terminal by two corrugated bakelite disks and (2) from the rain protecting funnel on the shaft by a small air gap. The conductor of the power circuit is a No. 14 insulated copper wire shielded by a flexible 5/8-in. armor. This cable is wound spirally about the vertical distributing bus and the end of the conductor is soldered to the galvanized cylinder of the terminal. The flexible armor is insulated from the cylinder and is fastened to the shaft of the terminal. To separate the insulator loss from the line loss, the loss over the insulators at the terminal end of the line may be eliminated by connecting the cap of the insulator next to the line to the shielding circuit as shown in Fig. 5. In this case the shielding circuit supplies the insulator losses. An extension of the shielding circuit to all of the insulators for the direct elimination of their losses from the power measuring circuit may be made when desired.

Operating Procedure for Atmospheric and Insulator Loss Measurements

The sphere gap is set for the voltage at which observations are to be taken. The valves of the water columns are opened. Voltage is then applied and

1. Trans. A. I. E. E., Vol. XXXII, 1916, p. 733.

gradually increased until the sphere gap flashes over. The readings of the four meters, W_m, I_C, I_L and V_m just in advance of the flash-over are noted and recorded. The barometric pressure and temperatures by wet and dry bulb thermometers are recorded at the beginning and end of each test.

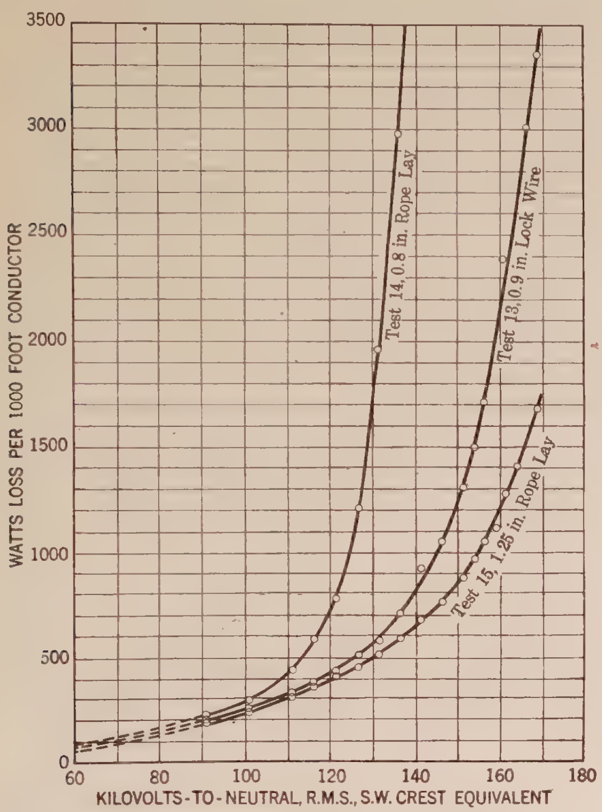

FIG. 6—TRANSMISSION LINE LOSSES MEASURED BY HIGH-VOLTAGE WATTMETER, STANFORD UNIVERSITY, CAL.

Fair weather, temperature 60 deg. fahr., humidity 58 per cent, barometer 30 in., frequency 60 cycles.

Test	13	14	15
Conductors.....	Smooth Lock Wire	375,000 Cm. Rope Lay	900,000 Cm. Rope Lay
Diameter.......	0.9 in.	0.8 in.	1.25 in.
Spacing........	17 ft.	17 ft.	18 ft.
Length.........	234 ft.	241 ft.	241 ft.

A typical test consisted of about 30 sets of readings with observations at 5-kilovolt intervals from 40 kilovolts to ground to 175 kilovolts to ground. Such a test under ordinary conditions required about 20 minutes and the services of at least five attendants.

Actual trials soon established that the wattmeter could handle voltages up to the maximum operating limit of the transformer long enough to accomplish satisfactory observations. At 170,000 volts to neutral the total power loss for 234 ft. of 0.9-in. diameter single conductor amounted to about 900 watts in fair weather. This corresponded to a 1.5-watt deflection on the 15-watt scale of the low-voltage range indicating wattmeter. The minimum operating range of the high-voltage wattmeter aggregation was determined by the sensitivity of the indicating wattmeter. At 50,000 volts to neutral the total atmospheric power loss from the 0.9-in. conductor was less than 20 watts and no readable deflection of the indicating wattmeter, as used, could be observed.

During April, 1923, this wattmeter aggregation was used to determine the single-phase atmospheric power losses from three pairs of large conductors in lengths of 240 ft. approximately, each, as follows: lock-wire, smooth cable, 0.91-in. diameter and rope-laid cables 0.8- and 1.25-inch diameters. For illustration, the results of three of these tests are chartered by means of rectangular coordinates in Fig. 6.

The possibility of error, due to neglecting the loss over the insulators, was investigated by making two tests,—(1) with the insulators normally connected to the line, and (2) with the insulator loss supplied by the shielding circuit as shown in Fig. 5. The insulator loss was so small that the indicating wattmeter was not sensitive enough to give quantitative results in clear weather, although a slight loss was perceptible.

CONCLUSION

The high-voltage direct-measuring wattmeter as reported herein was in a pioneer state. The application trials showed that it is not only practicable but advisable to use a wattmeter directly on high-voltage circuits. The next advance in the development of the wattmeter was the evaluation and elimination of the error powers due to capacitance effects in the loading and voltage circuits. Such study was undertaken by Messrs. Carroll, Peterson and Stray in the Stanford high-voltage laboratory. Their results have been embodied in a paper entitled Power Measurements at High Voltages and Low Power Factors presented concurrently to the American Institute of Electrical Engineers.

MEASUREMENT OF CYCLIC CHANGES OF RESISTANCE

Methods have been developed by the Bureau of Standards for the measurement of small cyclic changes in electrical resistance when such changes can be definitely synchronized with an alternating current. These depend for their action upon the rectification produced when an alternating current is passed through a conductor in phase with a change in its resistance, and are extremely sensitive and selective.

The sensitivity is such that under favorable conditions it is possible to detect a cyclic change in resistance when this change is no larger than a hundred millionth part of the resistance of the conductor in which it occurs, and the selectivity is such that a change in resistance of the same frequency as that of the test current can be measured while there are other changes which may be a thousand or even a million times larger. Further, the apparatus required for the use of these methods is fairly simple. It seems, therefore, that they may have a number of scientific and technical applications.

Equivalent Single-Phase Networks
for Calculating Short-Circuit Currents due to Grounds on Three-Phase Star Grounded Systems

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Review of the Subject.—*This paper presents a method for calculating the steady state value of the short-circuit current in a fault to ground on a power system operated with grounded neutral, and the distribution of this current throughout the system. Constant impedances and electromotive forces in the system, and electrically short lines, are assumed, and line capacitance is neglected.*

If, at the time the fault to ground occurs, the distribution of the load current in the system is known, the total current in any portion of the system under the short circuit condition may be calculated by means of this method. By "total current" is meant here the sum of that part of the fault current which appears in the branch considered, and the normal current in the branch due to the loads. The latter current, of course, does not appear in the fault.

Formulas and equivalent circuits for the usual three-phase transformer and generator connections used in practise, are given. The use of such circuits permits the calculation of the fault current and its distribution in the power system from an equivalent single-phase network. Since currents in a three-phase network under balanced conditions may also be calculated from a single-phase network, it is accordingly possible to calculate, entirely on a single-phase two-wire basis, the total current in any branch of a star grounded network for a ground on any phase.

The setting up of equivalent 2-wire single-phase networks similar to those for the three-phase case is not generally possible where the number of phases exceeds three.

The value of the method lies in its enabling one to calculate on a single-phase two-wire basis the short circuit current (steady state) due to a ground on a three-phase grounded neutral system, as regards both magnitude and distribution and taking into account all system loads. In the usual approximate method of making short-circuit calculations, a single-phase-to-neutral network is substituted for the actual network. While this method involves less labor than that proposed in the paper, the results obtained by it are inexact, the effect of non-grounded loads being usually ignored. The method of the paper involves much less work than that required by three-phase calculations giving equal accuracy.

An illustrative example is given.

Introduction

THE determination of the magnitude and distribution of currents in power lines under short-circuit conditions[1] is of large interest to all engineers engaged in power transmission problems. It is of interest also to telephone engineers, who are concerned with the inductive effects of these currents. It was from the latter standpoint that the studies on which this paper is based were undertaken. The results, however, are submitted here largely on account of their more general interest and utility.

Calculations of the magnitude and distribution of the fault or residual current, due to a ground on a non-grounded power system, are not difficult according to the methods worked out in Technical Report No. 52 of the Joint Committee on Inductive Interference of California.[2] The calculations are much more complex and difficult in the case of star-grounded power systems which is the case considered in this paper. Approximate calculations can, of course, be made by the well-known "equivalent single-phase to neutral" method. However, where substantial loads, either concentrated or distributed along the line, are located at points not remote from the position of the fault, the neglect of the residual current in the sound phases through these loads may lead to considerable errors in estimates of induced voltages. To the power engineer interested in accurate relay settings the additional accuracy of the proposed method may be of importance.

Considering a three-phase system for example, it is, of course, possible to take the loads into account by working out the currents on a three-phase basis. This is a laborious proceeding and the time involved is likely to be prohibitive if the network is at all complicated. By taking account of the symmetry, with respect to the faulty phase, presented by a normally balanced three-phase system, and by making use of a fictitious generator[3] in the fault in the place of all sources of e. m. f. in the power network, it is possible to simplify the calculation and to replace the three-phase network with a single-phase two-wire network that takes account of all loads. The method of doing this is described below.

In the case of a system of more than three phases it is, of course, still possible to replace all electromotive forces in the network by one at the fault. While this reduces the calculations to a single-phase basis, it is not generally possible to complete the simplification by replacing the network by a two-wire network.

Methods in common use for the approximate calculation of these fault currents are based on what amounts to an assumption of steady-state conditions. The same assumption underlies the methods to be discussed

1. O. R. Schurig, Journal A. I. E. E., June 1923, p. 605. This article contains a bibliography of the literature of the subject.

2. See "Inductive Interference," *California Railroad Commission*, 1919, pp. 353-376.

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

3. The possibility of using a fictitious generator in connection with problems similar to that under discussion here is referred to by L. P. Ferris (Transactions A. I. E. E. XLI, p. 90, Feb. 1922), in a discussion of a paper by Conwell and Evans.

in this paper. The determination of transient short-circuit currents is, of course, desirable. While methods have been devised for determining low-frequency transients by measurements in a model of the actual network under study,[4] it seems unlikely that the general calculation of transients can be simplified to such a point as to be of practical value to the operating engineer. Allowance is often made for the fact that maximum instantaneous values may be larger than the sustained values by the use of the so-called transient impedances. This can likewise be done in the application of the methods described in this paper.

An essential feature of the method here described is the reduction of the number of metallic conductors in the circuit to two. With a three-phase system, this can always be done in the case of a single fault to ground, assuming the system symmetrical. With certain other types of fault, this reduction cannot be readily effected, but some simplification is still usually possible by the replacement of the system electromotive forces by single electromotive forces at the fault or faults.

The magnitude and distribution of the short-circuit currents are the principal factors of interest in the power system, so far as induction into telephone circuits under abnormal conditions on a grounded neutral power system is concerned. The potential differences between any two points in the network may also be of interest in certain cases, however, and these may be readily determined by the method under discussion.

The following two well-known network theorems are the basis of the method to be described:

(a) Superposition Theorem: In any network with an arbitrary distribution of n e. m. fs. in its branches the current in any branch is the sum of the n currents which would be produced in this branch by the n electromotive forces taken separately in their respective positions in the network. (In applying this theorem, it is evident that instead of considering all the e. m. fs. separately they may be combined into groups in any desired way, subject, of course, to the condition that in the net result each shall have been used once and only once).

(b) In any network of impedances having an arbitrary distribution of e. m. fs. in its branches, the current in any branch is equal to the negative of the voltage across an open circuit in the branch, divided by the impedance of the network looking into this open circuit with all e. m. fs. removed.

Theorems (a) and (b) are true only providing there are no unilateral impedances in the networks.

The proof of theorem (b) follows at once from theorem (a). Referring to Fig. 1, the current I in the branch 1, 2 is the same as would be produced in that branch jointly by two superposed systems of electromotive forces, *viz.*:

(1) The n existing e. m. fs. plus an e. m. f. V_0 in the branch 1, 2 of such magnitude and phase that the current due to the n other e. m. fs. is exactly cancelled in branch 1, 2.

(2) A single e. m. f. $-V_0$ in the branch 1, 2.

Evidently the e. m. f. referred to in (1) is numerically equal to the open circuit voltage of branch 1, 2. Z being, as indicated, the impedance looking into the network from terminals 1, 2, the current in branch 1, 2 in case (2) is $-V_0/Z$, and it must be also I, since the total current in branch 1, 2 in case (1) is zero.

In connection with the application of this theorem to be made presently, it should be pointed out that the "existing e. m. fs." assumed to be removed, include not only e. m. fs. due to prime movers, but also those maintained by mechanical loads, in virtue of which they normally receive energy from the electrical system. It will be apparent from this that the method under discussion automatically takes into account the momentary return under short-circuit conditions of energy to the system from machines which are normally receivers.

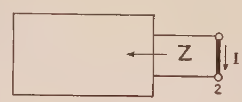

FIG. 1

METHOD OF CALCULATING SHORT-CIRCUIT CURRENT—THREE-PHASE SYSTEM

The following discussion describes by means of an example the manner in which the magnitude of the short circuit current through the fault may be calculated. Considering the network shown in Fig. 2, G is a star-connected generator; T, a bank of transformers connected in delta on the station side and star-grounded on the line side; S, a bank of (non-grounded) step-down transformers at the substation; and L is the substation load. The line has become accidentally grounded at E as shown. It is required to determine the short-circuit current to ground.

Let Z_g[5] = impedance of each generator winding

E_g = magnitude of induced generator voltage in each winding (Y-induced voltage)

Z_T = impedance of each transformer of bank T (low-tension basis)

U_T = ratio of transformation of each transformer of bank T

Z_s = impedance of each transformer of bank S (low-tension basis)

U_s = ratio of transformation of each transformer of bank S

Z_L[5] = impedance of each leg of the load

4. O. R. Schurig, JOURNAL A. I. E. E., October 1923, p. 1033.

5. This is the actual impedance, *i. e.*, the impedance in the absence of induced e. m. fs. representing the delivery of energy to or from sources external to the electrical system.

z'' = self impedance per mile of transmission line circuit composed of the two ungrounded conductors in parallel and the third conductor as a return.

z' = self impedance per mile of transmission line circuit composed of the two ungrounded conductors in parallel and earth return

z = self impedance per mile of transmission line circuit composed of the grounded conductor and earth return.

l = distance in miles from T to E

a = distance in miles from power house to substation.

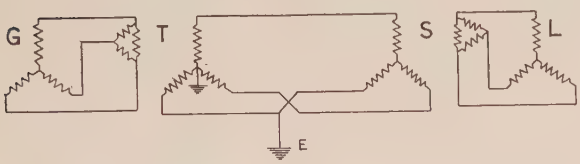

FIG. 2

The short-circuit current to ground may be obtained by the use of theorem (b), whose application to this case is illustrated in Fig. 3. In this figure, V_0 is the open circuit voltage at the fault, *i. e.*, the voltage to neutral of the system. The short-circuit current is $I + I_1$, I being the current in the faulty conductor directly to the neutral ground at T, and I_1 the current reaching the same point over a parallel path, E to S and the ungrounded conductors to T.

Applying Kirchhoff's voltage equation around the path taken by current I, and neglecting for the present the mutual impedance between the line circuits whose self-impedances are designated, z, z',

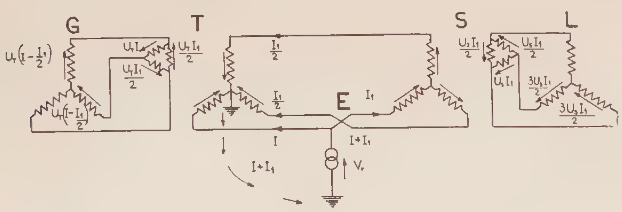

FIG. 3

$$V_0 - l z I - [(U_T I) Z_T + 2 Z_g U_T (I - I_1/2)] U_T = 0$$

or $$[l z + U_T^2 (Z_T + 2 Z_g)] I - U_T^2 Z_g I_1 = V_0 \qquad (1)$$

Similarly around the path taken by the current I_1

$$V_0 - (a - l) z'' I_1 - \left[2 Z_L \left(\frac{3 U_s}{2}\right) I_1 + Z_s U_s I_1\right] U_s - \left[Z_L \left(\frac{3 U_s}{2}\right) I_1 + Z_s U_s I_1/2\right] U_s - l z' I_1 - [- Z_g U_T (I - I_1/2) + Z_T (U_T I_1/2)] U_T = 0$$

or $$-(U_T^2 Z_g) I + [(a - l) z'' + l z' + (3/2) U_s^2 (3 Z_L + Z_s) + (U_T^2/2)(Z_T + Z_g)] I_1 = V_0 \qquad (2)$$

From (1) and (2)

$$I/I_1 = \frac{(a - l) z'' + l z' + (3/2) U_s^2 (3 Z_L + Z_s) + (U_T^2/2)(Z_T + 3 Z_g)}{l z + U_T^2 (Z_T + 3 Z_g)} \qquad (3)$$

From equation (1) and (2) $I + I_1$ may be obtained.

When the mutual impedance, which may be denoted by z_m, between the circuits whose self-impedances are designated z and z', is taken into account, equations (1) and (2) become

$$[l z + U_T^2 (Z_T + 2 Z_g)] I - [(U_T^2 Z_g - l z_m)] I_1 = V_0 \qquad (4)$$

$$(- U_T^2 Z_g + l z_m) I + [(a - l) z'' + l z' {}^{2} + (3/2) U_s^2 (3 Z_L + Z_s) + (U_T^2/2)(Z_T + Z_g)] I_1 = V_0 \qquad (5)$$

In calculations of short-circuit currents z_m is frequently disregarded. In some cases rather large errors may result from disregarding it, and where accuracy is desired, it should be included unless it can be shown that its effect is unimportant.

DISTRIBUTION OF CURRENTS

The magnitude of the short-circuit current *through the fault* may thus be obtained as outlined above. It

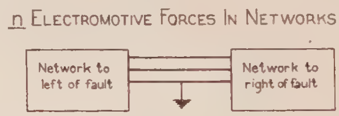

FIG. 4

is usually necessary, however, to determine the current *in some specified branch* of the network other than the fault itself. The *total* current in any branch may be considered as made up of two currents, namely, the portion of the fault current in the branch, and the normal current due to the system loads. The latter current, of course, does not appear in the fault. These currents may be determined as follows: Figs. 4, 5 and 6 represent the power network under three conditions, namely: (1) the actual network (Fig. 4) with the fault as shown; (2) the actual network after removing all sources of e. m. f. (but not the impedances of the windings in which they are generated), and with the fictitious generator of voltage V_0 in the fault (Fig. 5); and, (3) the actual network (Fig. 6) with the fictitious generator. By the superposition theorem, the difference of the currents in any branch for the conditions exhibited by Figs. 5 and 6 gives the current for the condition of Fig. 4 and this is the desired result, namely, the total current in that branch under the conditions of fault. The current in the branch due to the arrangement of Fig. 5 is (aside from a 180-deg. phase displacement) the portion of the *fault current*

in the branch, and may be calculated by means of the formulas given in the preceding section. Since V_0 is equal to the open circuit voltage at the fault, the currents obtained with Fig. 6 are those in the power network with the fault removed, *i. e.*, the load currents. Consequently, the total current in any branch of the network is obtained by means of the method of analysis above outlined.

Although theorems (a) and (b) have thus far been applied to a particular network, it is apparent that they may be applied in a similar manner to other types of network as well. The treatment of a large number of three-phase network elements commonly found in high-tension transmission systems by this method is given in the next two sections.

In most cases of inductive interference with communication circuits, due to grounds on star-grounded power systems, the fault or residual currents are many times more important as regards inductive effects than the normal-load currents (which do not appear in the fault). Consequently it is sufficiently accurate

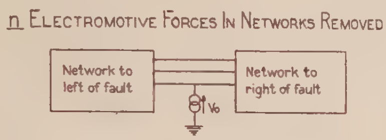

Fig. 5

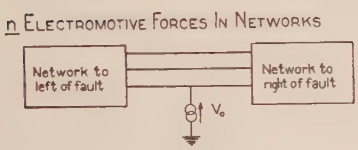

Fig. 6

in such cases to consider only the magnitude and distribution of the fault current. In such cases it is necessary to consider merely the network typified by Fig. 5.

Equivalent Two Terminal Networks for Three-Phase Systems

The preceding discussion has shown how to replace the three-phase system with a single-phase system. In applying the results, it is convenient to have equivalent two-terminal impedances to replace the three-terminal impedances presented by power apparatus at generating and substations.

Returning to the arrangement shown in Figs. 2 and 3, and assuming symmetry in the three phases, it is evident that the two sound conductors may be replaced by a single conductor as $F D$ in Fig. 7. To determine equivalent two-terminal impedances for the generating and substations for use with the resulting two-wire system, we may further assume impedances Z, Y and X with mutual impedance M between Z and Y, as indicated in Fig. 7. These impedances are then to be determined in terms of the impedances of the generator, load and transformers. The impedances of the branches, $A B$ and $E F$, Fig. 7, will evidently be z and z' ohms per mile and that of $B C$, with $D E$ as return, z'' ohms per (loop) mile, by the preceding work. (These ignore mutual impedance between the circuits whose self-impedances are z and z'. If this cannot be ignored, it is necessary to assume a mutual impedance z_m between $A B$ and $F E$.) Then

$$V_0 = l z I + Y I - M I_1$$

$$V_0 = [(a - l) z'' + X + l z' + Z] I_1 - M I$$

By comparison with the equations (1) and (2)

$X = (3/2)\, U_s^2\, (Z_s + 3\, Z_L)$

$Y = U_T^2\, (Z_T + 2\, Z_g)$

$Z = (U_T^2/2)\, (Z_T + Z_g)$

$M = U_T^2\, Z_g$, and represents the voltage *drop* from G to F per ampere from A to G or the voltage drop from G to A per ampere from F to G

By similar processes, the equivalent networks for the various transformer connections exhibited in the diagrams of Figs. A and B may be obtained.

In these diagrams the symbols U, U' and U'' refer to transformer ratios from line side to station side and the impedances Z_T, Z_g, Z_T', Z_g', etc. to transformer

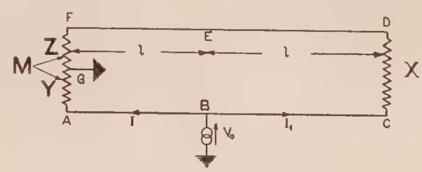

Fig. 7

or machine winding impedances on the station-side voltage basis. Diagrams 13 to 18 inclusive deal with 3-winding transformers.[6] It is to be noted that in the diagrams for the open delta (19 and 20) and Scott (21, 22 and 23) connections the accidental ground is assumed to exist on the phase, with respect to which the other two phases are symmetrical. Diagrams 24 and 25 illustrate combinations of some of the network elements with line circuits.

The scheme of reduction of the three-phase system to a single-phase system which has been described, assumes electrical symmetry, not only in apparatus but also in lines. In practical cases, dissymmetry in lines when untransposed is probably the only dissymmetry which it might be necessary to consider and even here, it is probable that if mean self and mutual impedances are used, the error from assuming symmetry would be small.

Systems of More than Three Phases

The setting up of equivalent two-wire single-phase network elements similar to those shown in the diagrams of Figs. A and B is not generally possible where the number of phases exceeds three. Where only

6. For theory of the 3-winding transformer see Peters and Skinner, A. I. E. E. 1921 Trans., pp. 1181-1199. Also Boyajian A. I. E. E. Journal, April 1924, pp. 345-355.

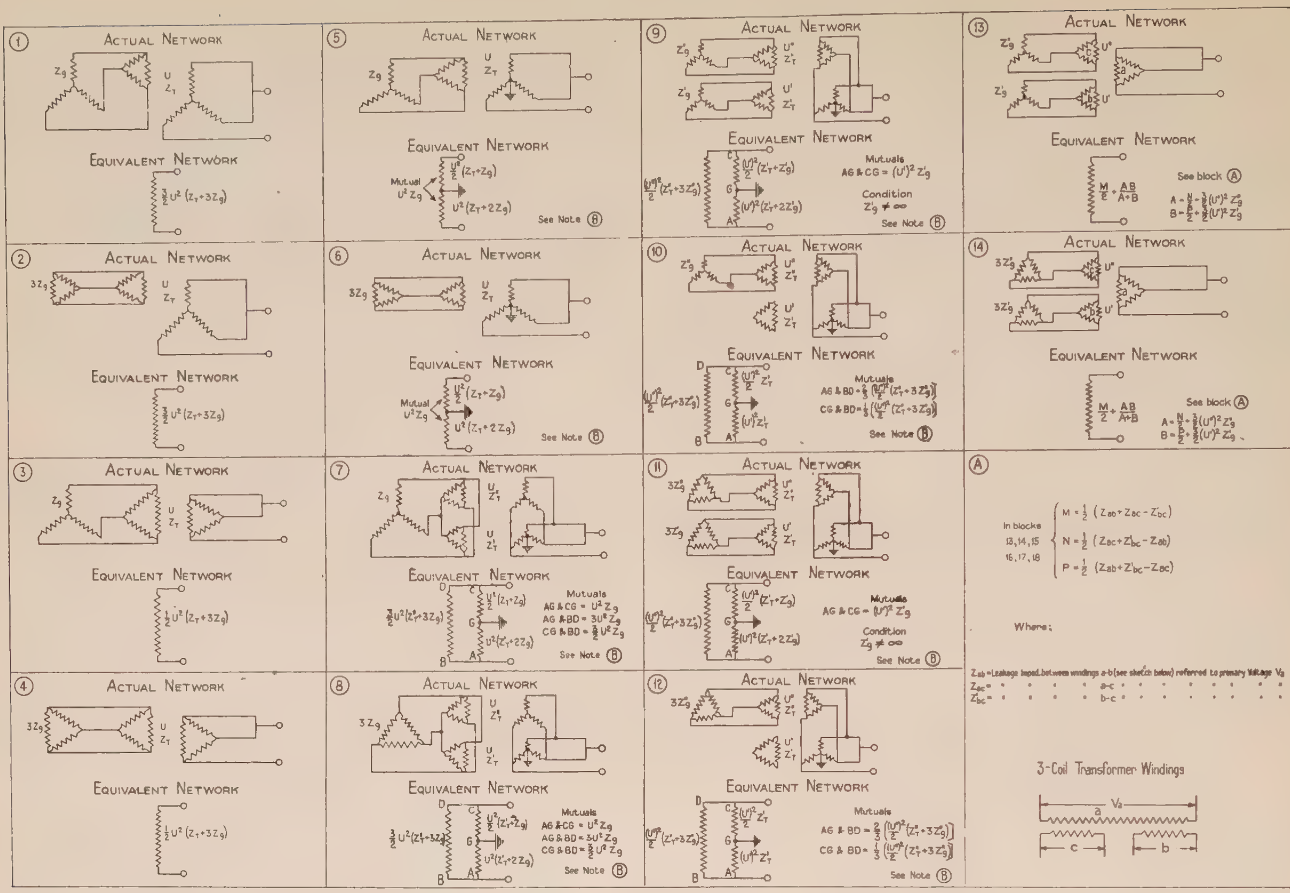

FIG. A

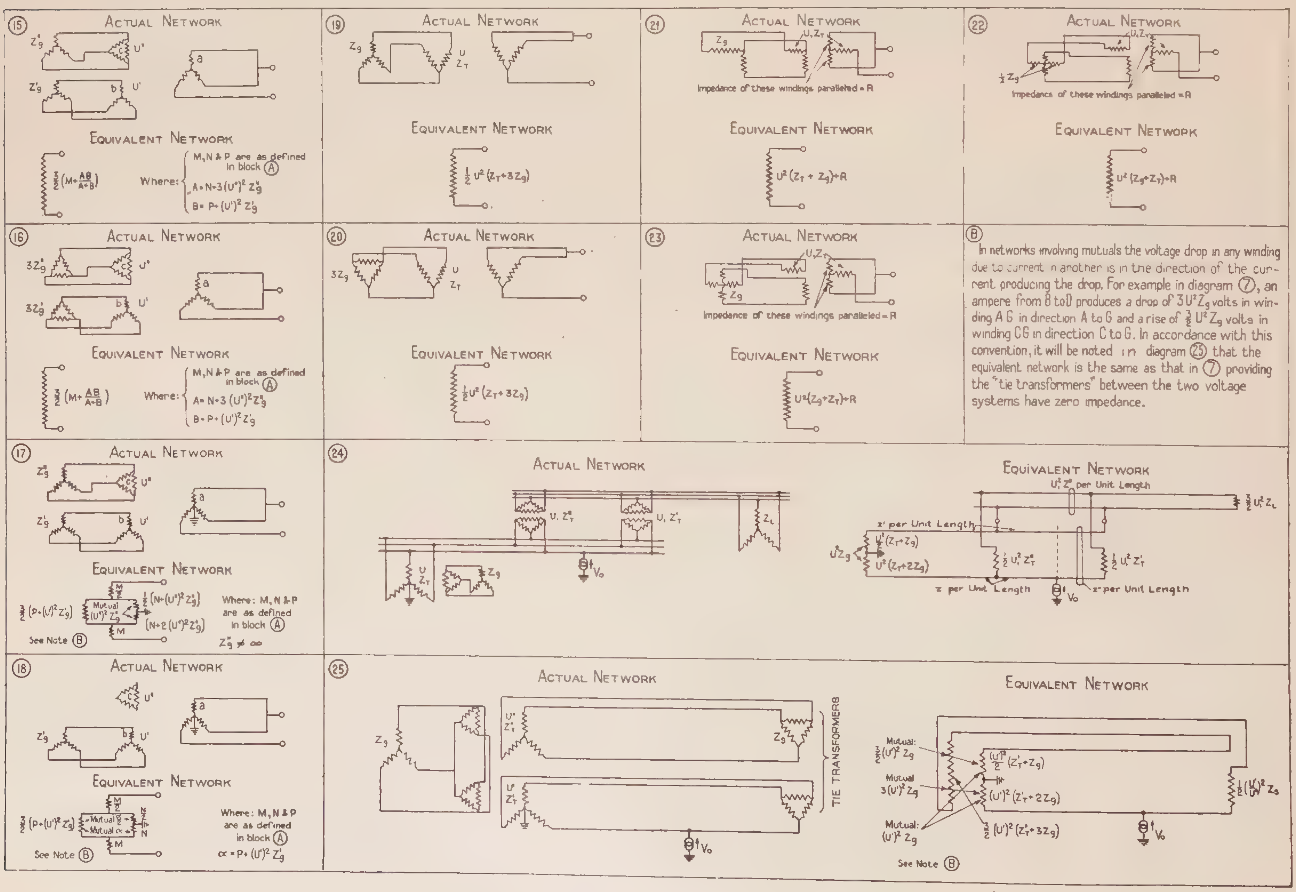
In networks involving mutuals the voltage drop in any winding due to current in another is in the direction of the current producing the drop. For example in diagram (7), an ampere from B to D produces a drop of $3U^2Z_g$ volts in winding AG in direction A to G and a rise of $\frac{3}{2}U^2Z_g$ volts in winding CG in direction C to G. In accordance with this convention, it will be noted in diagram (25) that the equivalent network is the same as that in (7) providing the "tie transformers" between the two voltage systems have zero impedance.

FIG. B

three phases are involved, the two sound phases are symmetrical with respect to the faulty phase (assuming, of course, equality in line and apparatus constants for the three phases). With four or more phases, however, except in very special cases, the three or more sound phases do not form a system having complete symmetry with respect to the faulty phase, and they therefore cannot be combined with the faulty phase, by formulas of general validity, to form a single-phase two-wire network

Illustrative Example

The network of Fig. 8 consists of 44-kv. and 110-kv. lines interconnected at three places, fed by four generating stations and supplying one large load. The kilovolt-ampere capacities of all machines and transformers, the connections of the transformers, and the lengths of the several transmission circuits, with sizes of conductors, are indicated in the figure. The method developed above will be applied to the calculation of the residual current in the various branches of this network due to a ground on one phase of the 44-kv. line at a point 28 mi. to the right of station B.

The equivalent single-phase two-wire network is shown in Fig. 9. Diagrams 1, 3, 5, 24 and 25, of Figs. A and B are used to obtain the equivalent networks. For the condition assumed, grounded apparatus on the 110-kv. lines behaves as though ungrounded.

In determining the impedances of the various branches, the resistance components have, for simplicity been neglected. The percentage reactances of all transformers and generators or loads have been taken at 5 and 10 per cent respectively. The reactances

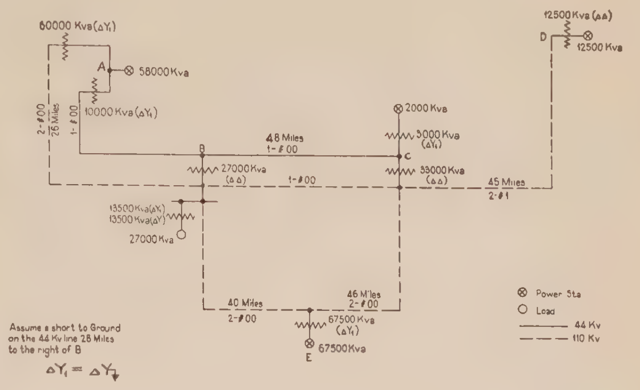

Fig. 8

in ohms of the machines and transformers are found from the percentage reactances and kilovolt-ampere

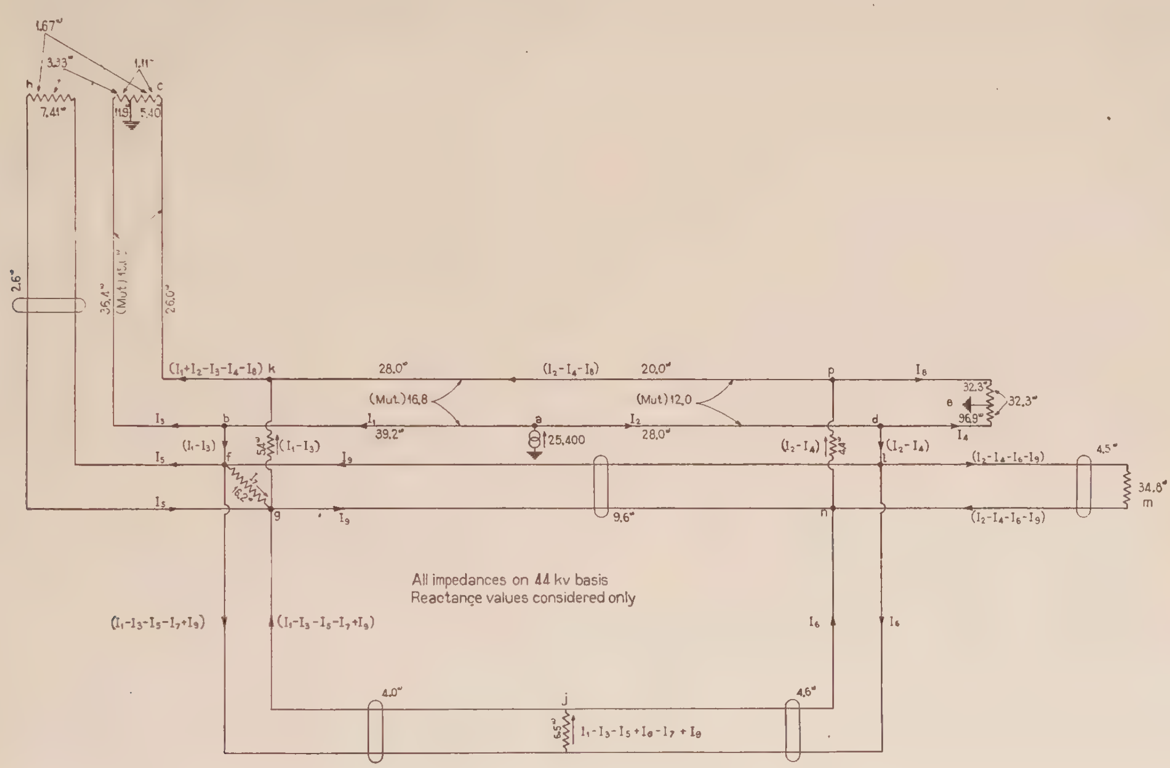

Fig. 9

capacities in the usual way, and the numerical values of the impedances of the various equivalent networks may then be found at once. Thus, for the case of generating station A, using the notation of diagram 25, Fig. B,

$$Z_g = (10/100.)\frac{V^2}{1000 \text{ kv-a.}}$$

$$(U')^2 Z_g = (10/100).\frac{V^2\left[\dfrac{44{,}000}{\sqrt{3}\,(\sqrt{3}\,V)}\right]^2}{1000\,(58{,}000/3)} = 1.11$$

and similarly

$$(U')^2 Z_T' = \frac{5 V^2 \left[\frac{44{,}000}{\sqrt{3}\, V} \right]^2}{100\ (1000)\ (10{,}000/3)} = 9.68,$$

$$(U')^2 Z_T'' = 9.68/6 = 1.61;$$

Consequently

$$\frac{(U')^2}{2} (Z_T' + Z_g) = 5.40;\ (3/2)\ (U')^2 Z_g = 1.67$$

$$(U')^2 (Z_T' + 2 Z_g) = 11.9;\ 3\ (U')^2 Z_g = 3.33$$

$$(3/2)\ (U')^2 (Z_T'' + 3 Z_g) = 7.41;\ (U')^2 Z_g = 1.11$$

The equivalent impedances of the other generating and load networks may be similarly determined and are given in Fig. 9. In all cases they are on a 44-kv. basis.

As regards the transmission lines, the reactances of circuits composed of one and two (similar) wires with ground return are given approximately by the following formulas:

$$x = 0.00465\, f \log_{10} \frac{2\, h}{r} \text{ ohms/mile (one wire)}$$

$$x = 0.00233\, f \log_{10} \frac{(2\, h)^2}{r\, D} \text{ ohms/mile (two wires)}$$

where f is the frequency in cycles per second, r is the radius of, and D the distance between, the wires, and h is the depth of the equivalent ground plane.[7]

Substituting $f = 60$, $r = 0.182$ inches (00 wire), $D = 8$ ft. and $h = 500$ ft., it is found that

Reactance of one wire with earth return equals 1.4 ohms per mile.

Reactance of two wires (8 ft. spacing) with earth return equals 1.0 ohms per mile.

Also, the reactance of a metallic circuit composed of one wire as one side and two wires in parallel as the other is about 1.2 ohms per mile; and of a circuit composed of two wires as one side and four wires as the other, about 0.6 ohms per mile..

The mutual impedance z_m between two circuits having the ground as a common side and one and two wires respectively as the other sides may be computed from the formula

$$z_m = 0.00465\, f \log_{10} \left(\frac{2\, h}{D} \right) \text{ ohms/mile}$$

where f is the frequency in cycles per second, h is the depth of the equivalent ground plane and D is the distance between the wires of the two circuits. From this, using the same values for f, h and D as before

$$z_m = 0.6 \text{ ohms/mile}$$

The impedances (neglecting resistances) of the various transmission line circuits resulting from these figures are given in Fig. 9 (all on a 44-kv. basis).

The remainder of the work consists in solving the network for the currents whose magnitudes are desired, using Kirchhoff's laws. For the case under discussion, the currents (for notation refer to Fig. 9) are found to be

$I_1 = 395$	$I_4 = 222$	$I_7 = 105$
$I_2 = 557$	$I_5 = 177$	$I_8 = 380$
$I_3 = 149$	$I_6 = 198$	$I_9 = 75$

These, of course, do not include the normal load currents.

It is interesting to note the difference in the calculated residual currents as determined by the single-phase-to-neutral method and by the method given in this paper. The results based on the same line and apparatus impedances for the two methods are as follows:

Section	Ground Currents	
	Single-Phase-to-Neutral Method	Method given in this Paper
Fault to Station B	290	350
Station B to Station A	290	350
Fault to Station C	203	602

The large difference in the two currents designated "Fault to Station C" is due to the fact that the impedances between points designated d and e and p and e (Fig. 9) are relatively large, while those from p to n and in the 110-kv. network are small. Consequently, current finds a relatively easy path from d through the 110-kv. network to the two sound phases of the 44 kv. circuit thence to the ground at C, which path is ignored in the single-phase-to-neutral method. The difference in the other currents is only 21 per cent as based on the values obtained by the single-phase-to-neutral method.

In conclusion, I wish to express my appreciation of many valuable suggestions received from H. M. Trueblood. I am also indebted to C. M. Hebbert for checking the mathematical deductions.

7. For four wires with ground return $x = 0.00058\, f \log_{10} \frac{(2\, h)^8}{12\, r^2\, D^6}$ ohms/mile. See Technical Report No. 64 in "Inductive Interference." (*California Railroad Commission*, 1919), pp. 653, 654. Also see page 171 where curves and formulas showing the inductance of circuits with ground return are given.

THE STANDARDIZATION OF TESTS FOR DRY CELLS USED IN RADIO RECEIVING SETS

"The Standardization of Tests for Dry Cells Used in Radio Receiving Sets" is a report of the Radio Battery Committee, presented at the Philadelphia Meeting of the American Electrochemical Society in the spring of this year. This report was subsequently adopted by the conference of manufacturers and users of dry cells. It will be noted that the appendix of this report contains the minimum requirements for tests adopted by the Bureau of Standards. Copies may be obtained from the American Electrochemical Society at 25c. each.

Heating of Large Steel-Cored Aluminum Conductors

BY R. J. C. WOOD

Associate, A. I. E. E.

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STUDIES of the most economical size of conductor for the Southern California Edison Company's third 220-kv. transmission line from Big Creek to near Los Angeles led to the choice of either a 1,033,500-cir. mil aluminum steel core or the equivalent 650,000-cir. mil copper cable.

The normal full-load current in this conductor will be about 450 amperes and when a fourth line is put into service, paralleled and cross-connected with the third circuit, it appears probable that sections of the line may be required to carry 900 amperes continuously over periods of time.

The temperature rise of such cables carrying these large currents might prove to be a limitation which would have to be considered, not on account of fusing or burning, but because of the expansion and consequent increased sag in the transmission line which might reduce clearances unduly.

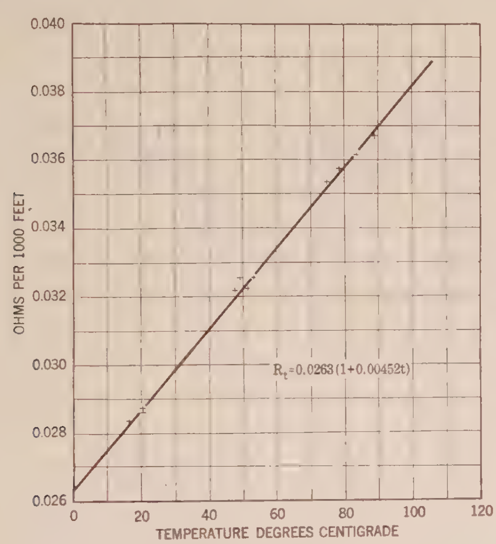

FIG. 1—TEMPERATURE COEFFICIENT OF RESISTANCE 605,000-CIR. MIL ALUMINUM STEEL CORE CABLE

The rulings of the California State Railroad Commission require, at 130 deg. fahr. a minimum clearance to ground of 30 ft. over territory susceptible of cultivation and accessible to vehicles, and over highways and railroads. This provides an ample margin, but special cases occur, such as crossing other circuits either of the same or other companies' systems where insufficient clearances might be allowed, if the reduction in them, due to conductor heating, were not taken into consideration.

A series of tests was therefore made to determine the temperature rise, both in still air and in wind, of three sizes of aluminum steel-cored cable; tests upon copper to be made at a future date.

The first tests were upon new clean cable of 666,000 cir. mils.

Afterwards, a sample of 605,000-cir. mil cable cut from the Big Creek transmission line was tested. This cable had become coated with a hard, smooth, black deposit which forms on the conductor at high voltages

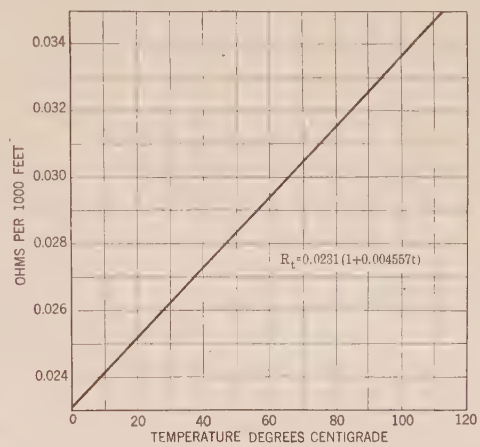

FIG. 2—TEMPERATURE COEFFICIENT OF RESISTANCE 666,000-CIR. MIL ALUMINUM STEEL CORE CABLE

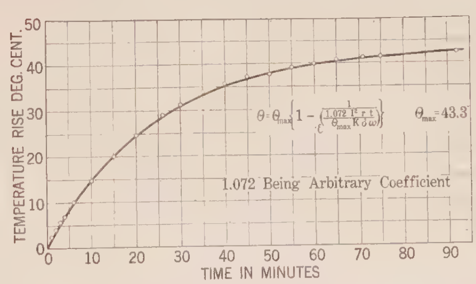

FIG. 3—HEATING CURVE OF 666,000-CIR. MIL CABLE CARRYING 602 AMPERES

by electric precipitation from the air. This coating can only be removed with difficulty even by scraping; incidentally it reduces corona loss, probably by reason of the mechanical smoothness imparted to the conductor.

Finally, the heating of new clean 1,033,500-cir. mil cable was determined. It should be noted that these sizes as here given do not include the steel core.

The tests were made indoors in the corner of a large room remote from doors and windows. A length of

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about 20 ft. of cable was suspended so that about six feet was horizontal at a height of seven feet above the floor and six feet below the ceiling; the ends of the cable were brought around to the supply transformer furnishing 50-cycle low-voltage current. The loop of cable thus formed an oval about nine by six feet, its plane inclined to the vertical, to prevent heated air rising into the upper portion.

Attempts were first made to measure temperatures with thermometers, but these were abandoned in favor of a copper-constantin thermo couple having its hot junction placed in the second layer of stranding of the

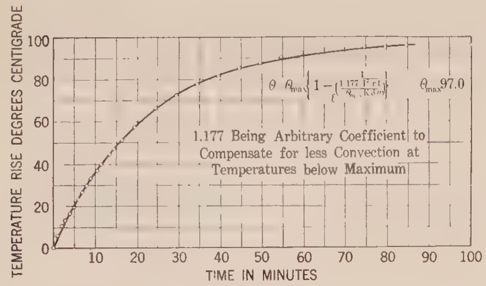

Fig. 4—Heating Curve of 666,000-Cir. Mil Cable Carrying 900 Amperes

cable, counting from the outside. The cold junction was similarly embedded in a 24-in. length of cable suspended 12 in. below the horizontal portion of the cable under test. This arrangement gave consistent results, measured the temperature rise directly, and was sensitive to 1 deg. cent; stem effect or conduction of heat by the thermocouple wires was practically eliminated by wrapping them once round the circumference of the cable, insulated from it by a single layer of thin paper continued once around outside the thermo couple wires and bound in place.

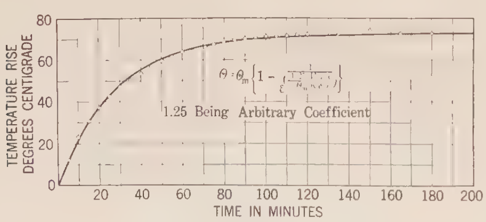

Fig. 5—Heating Curve of 1,033,000-Cir. Mil Cable Carrying 1029 Amperes

The final temperature rise resulting from different amounts of current was determined, as well as the rate of heating from the time the current was first turned on until a steady temperature was reached, this requiring from 1.5 to 2 hours. From these observed results the watts dissipated per square inch of surface were calculated, the surface being considered as that of a cylinder of diameter equal to the maximum outside diameter of the cable. The rate of heat emission per degree of temperature rise increases with temperature difference as shown in Fig. 6. As might be expected, the black coating referred to above increases the rate of heat emission.

The observed results differ materially from the data published by George E. Luke in the *Electric Journal*, Apr., 1923. Luke found that the temperature rise was practically proportional to the watts dissipated and that the color and nature of the surface had but little effect upon the specific rate of heat dissipation, whereas in our experiments the rate of heat dissipation was found to be about 66 per cent more at 100 deg. cent. rise than at 10 deg. cent. rise and to increase 17 per cent even between 30 deg. cent. and 60 deg. cent. temperature rise. Blackened aluminum cable dissipated 40 per cent more energy than bright cable with equal temperature rise. It is not to be expected that Luke's curves for the temperature rise of aluminum cables would agree closely with observations made upon steel-cored cable, as the latter has a relatively larger surface.

Wind was produced horizontally by from one to three 12-in. desk fans appropriately placed so as to distribute the air current as evenly as possible, the velocity of the

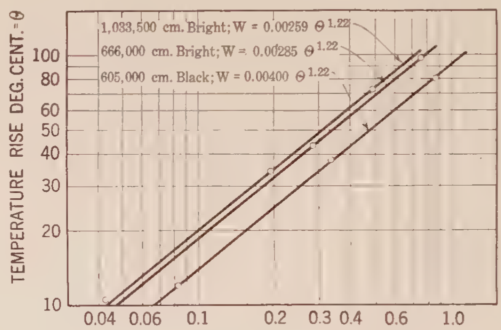

Fig. 6—Heat Dissipated in Watts per Square Inch of Surface

wind was measured by an anemometer calibrated during the tests. This artificial wind differs from natural winds in being very much more constant and in lacking the gusts and eddies of nature, but since the additional emissivity due to wind is approximately a linear function of velocity over a considerable range, the cooling effect as determined should agree with that produced by natural winds of the same average velocities.

When it comes to the application of the results to transmission line design, the effect of wind in cooling the conductor is of great importance, even an almost imperceptible breeze of 0.2 miles per hour has a very marked cooling effect. More information is needed upon the minimum air velocities that may be coincident with maximum air temperatures in different localities.

From the data, empirical equations were obtained for the watts lost per square inch of surface, both clean and black, and for the additional convection losses due to wind, and it is believed that these equations are reliable for engineering purposes within the range of sizes covered by the experiments, and may be

used without probability of material error between the limits of 500,000 to 2,000,000-cm. cables.

Resistance measurements were made by drop of potential method at different temperatures as the cable cooled naturally after a heat run. The temperature coefficient of resistance calculated from this data is slightly higher than previously published; a probable explanation is that when heated the aluminum stranding, expanding more than the steel core, loosens somewhat, decreasing the contact pressure between strands and layers. In a suspended conductor under considerable tension this effect will be less or absent. In order to be on the safe side, the coefficient as found was used in the derived equations.

TABLE I

CONSTANTS OF CABLES

Nominal Size Cir. Mils	Aluminum Cir. Mils	Steel Cir. Mils	Total Cir. Mils	Weight Al.	1000 ft. Steel	No. of Strands Al.	No. of Strands Steel	Dia. of Cable Inches
605,000	605,000	78,000	683,000	568	211	54	7	0.954
666,000	666,000	86,000	752,000	626	232	54	7	1.000
1,033,500	1,033,500	134,000	1,167,500	971	353	54	7	1.247

TABLE II

OBSERVED DATA, HEATING OF CABLES

Size cm. Nominal	Surface	Wind ft/min.	Current Amps.	Temp. Rise Deg. Cent.	Temp. of Cable Deg. Cent.	Ohms per 1000 ft.	Watts per Sq. In.
605,000	Black	0	314	12.0	32.8	0.03027	0.08295
"	"	0	600	38.0	59.0	0.03335	0.334
"	"	0	902	80.0	100.0	0.03823	0.8654
"	"	97	905	55.2	77.8	0.03558	0.8108
"	"	170	907	47.0	69.8	0.03462	0.7926
666,000	Bright	0	602	43.3	62.3	0.02965	0.2857
"	"	0	900	97.0	117.0	0.0354	0.7605
"	"	96	900	57.5	73.5	0.03083	0.6622
"	"	175	900	47.0	66.0	0.03004	0.6455
"	"	300	900	34.8	53.8	0.02877	0.6180
1,033,500	Bright	0	338	10.5	36.1	0.01751	0.04259
"	"	0	690	34.3	60.4	0.01915	0.1940
"	"	0	1029	72.6	98.7	0.02175	0.4903

In Figs. 3, 4 and 5 are shown the observed rate of heating compared with an equation of rational form but containing an empirical coefficient.

It may be shown that when

I = current in amperes
r = resistance in ohms of unit length
a = temperature coefficient of resistance
U = coefficient of heat emission from surface
t = time
O = temperature rise above air
K = heat equivalent in watt seconds
σ = specific heat of cable
w = weight of cable per unit length

$$\text{Then } \theta = \frac{B}{A}\left\{1 - \frac{1}{e^{At}}\right\}$$

and the final temperature rise after a long time is

$$\theta_m = \frac{B}{A}$$

$$\text{So that } \theta = \theta_m \left\{1 - \frac{1}{e^{At}}\right\} \tag{1}$$

$$\text{where } A = \frac{U - a\,I^2\,r}{K\,\sigma\,\omega}$$

$$B = \frac{I^2\,r}{K\,\sigma\,\omega}$$

always provided that U does not vary with θ. As a matter of fact U does vary with θ as is shown in Fig. 6.

It will be noted that the observations as plotted indicate quite consistently an exponential relation between temperature rise and watts dissipated and that within the limits of expected error the value of the exponent is the same for all three cables, including both bright and black surfaces.

The substitution of the equation for U in the differential equation of temperature rise leads to an unwieldy integral. The heating curve for bright cable may be closely approximated, however, by the equation

$$\theta = \theta_m \left\{1 - \frac{1}{e^{\left\{\frac{I^2\,r\,t}{[1 - (.0043\,I)^2]\,\theta_m\,k\,\sigma\,\omega}\right\}}}\right\} \tag{2}$$

this is the equation of the solid lines in Figs. 3, 4 and 5, and is of the same form as equation (1) when

$$A = \frac{I^2\,r}{[1 - (.00043\,I)^2]\,\theta_m\,K\,\sigma\,\omega}$$

The agreement with the observed rate of temperature rise is sufficiently good for practical purposes. The number of different sizes of cable used is, of course, much too few to establish a law connecting size with coefficient of heat emission, but the nature of the phenomena suggests an exponential equation which cannot be greatly in error within reasonable limits since the change in emission is small over a large range in cable size. In Luke's paper, above referred to, this matter is considered much more fully, and a curve of dissipation constant and cable diameter is given. This curve is an exponential one lending strong support to the assumption as to the form of the curve.

Only one size of blackened cable was obtainable and it is assumed tentatively that the curves for black and

bright cables are parallel, which is the same thing as assuming that the ratio of the dissipation constants of bright and black cables of the same size shall be constant and independent of their absolute size.

Fig. 7 shows how the heat emission varies with the size of the cable which is here given, including the area of the steel core. The equation of loss is

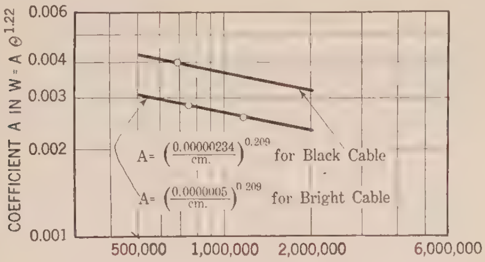

FIG. 7—COEFFICIENT OF HEAT DISSIPATED AS A FUNCTION OF THE SIZE OF THE CABLE

$$W_s = \left\{ \frac{0.00005090}{\text{cir mils}} \right\}^{0.25} \theta^{1.22} \text{ for bright cable} \qquad (3)$$

$$W_s = \left\{ \frac{0.0001815}{\text{cir mils}} \right\}^{0.25} \theta^{1.22} \text{ for black cable} \qquad (4)$$

where W_s = watts dissipated per square inch of surface. To obtain watts per square inch per 1 deg. cent. the exponent of θ will be 0.22.

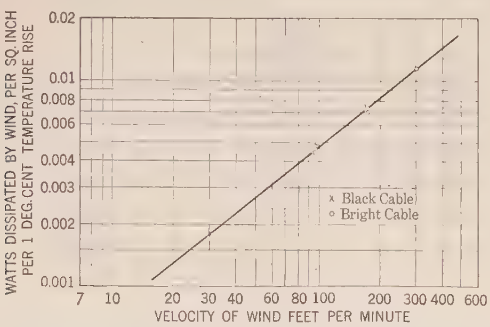

FIG. 8—HEAT DISSIPATED BY WIND IN WATTS PER SQUARE INCH PER DEGREE TEMPERATURE DIFFERENCE

The effect of wind is given in Fig. 8 and Table III. The additional heat loss due to wind over and above what would exist in still air is shown as a function of air velocity.

The loss is nearly the same for bright and black cable as would be expected. This loss is given by

$$W_w = 0.0001185\, V^{0.8} \qquad (5)$$

where W_w = watts dissipated per square inch

V = velocity of air feet per minute.

The total loss from the cable is therefore given by

$$W = \left\{ \frac{0.00005090}{\text{cir. mils}} \right\}^{0.25} \theta^{1.22} + 0.0001185\, V^{0.8}.$$

for bright cable (6)

$$W = \left\{ \frac{0.0001815}{\text{cir. mils}} \right\}^{0.25} \theta^{1.22} + 0.0001185\, V^{0.8}.$$

for black cable (7)

TABLE III

Watts Dissipated by Wind

666,000 cm. Bright Cable

Wind Ft/Min.	Temp. Rise Deg. Cent.	Watts per Sq. Inch per 1 Deg. Cent. Total	Loss in Still Air	Loss due to Wind
96	57.5	0.01152	0.00700	0.00452
175	47.0	0.01373	0.00669	0.00704
300	34.8	0.01776	0.00626	0.01150
605,000 cm. Black Cable				
97	55.2	0.01468	0.00973	0.00495
170	47.0	0.01686	0.00943	0.00743

W being watts per square inch of surface.

The heat generated in the cable is

$$W = \frac{I^2\, r_o\, [\, 1 + a\,(\theta + t)\,]}{S} \qquad (8)$$

where t = temperature of atmosphere

S = Surface area of a length of cable having resistance r_0 at O deg. cent.

The final temperature rise is easily obtained graphically at the intersection of the curves plotted from equations (6) and (8) or (7) and (8). The method of doing this is illustrated in Fig. 9, the curves giving heat

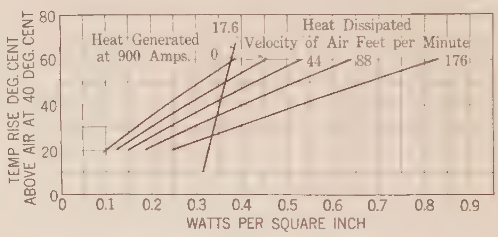

FIG. 9—HEAT DISSIPATED IN STILL AND MOVING AIR FROM BRIGHT 1,033,500-CIR. MIL CABLE, AND HEAT GENERATED AT 900 AMPERES.

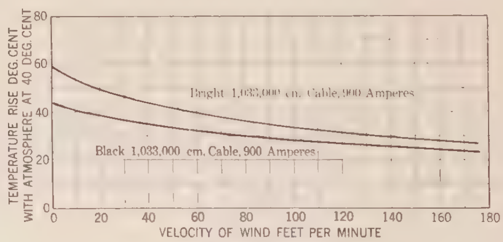

FIG. 10—FINAL TEMPERATURE RISE OF 1,033,500-CIR. MIL CABLE CARRYING 900 AMPERES

dissipated as per equation (6) and the straight line giving heat generated plotted from equation (8). Intersections are in equilibrium giving the final temperature rise. A cross plot from Fig. 9 and other similar curves are shown in Fig. 10 which presents the final results in a more agreeable manner.

The probable increase of effective resistance of these steel-cored cables on alternating current has not been separately considered but is included in the empirical coefficients.

Transmission at 220 Kv.

on the Southern California Edison System

A SYMPOSIUM

(*Continued from page 908.*)

Section 3B—Economic Studies of Transmission Line Design with Particular Reference to the Electrical Features

BY W. D. SHAW

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INITIAL CONDITIONS

Length of line was to be 275 miles. This was determined by the fact that the present Big Creek lines from Big Creek to Eagle Rock Substation are 243 miles in length and the lines from Eagle Rock to Laguna Bell Substation are 26 miles or a total length of 269 miles. Assuming that the future lines would terminate at Laguna Bell or in the same neighborhood, the round figure of 275 miles was used.

The spacing of conductors was to be 22 ft. using a flat constructure and was determined by the studies on tower design as outlined elsewhere in this paper.

The voltage was to be 220,000 volts at the generating end and 200,000 volts at the receiving end; this was determined by the voltage of the present Big Creek lines. The power factor of the load is 80 per cent lagging.

LINE CHARACTERISTICS

With the above conditions fixed, the first step was to determine the auxiliary line constants for different size

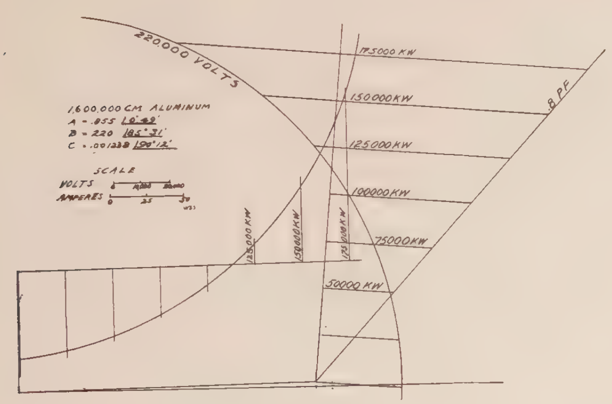

FIG. 13

cables, varying from 600,000 to 1,600,000 circular mils, the lower limit being just below the size of the original Big Creek line. Due to corona, it would not be desirable to use a cable with as small a diameter as the present line.

The constants of the line alone were calculated by the usual hyperbolic method, then the constants of the line in combination with the sending and receiving transformers were found by the method outlined by R. D. Evans and H. K. Sels in the *Electric Journal* of August, 1921. The capacity of the transformers was sufficient to deliver 150,000 kw. at the receiving end.

The final results are shown in Table I.

The 650,000-cir. mil copper is of special design wound over a hollow copper tube which gives it a larger diameter than the ordinary stranded copper cable of the same cir. mil cross section.

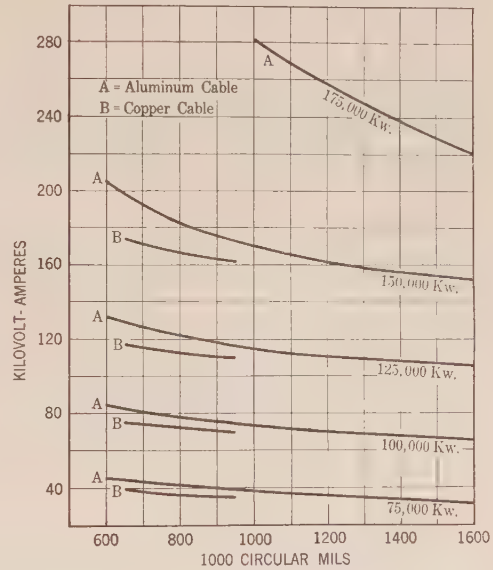

FIG. 14

With the constants determined, the graphical method as outlined in C. H. Holladay's paper in the A. I. E. E. JOURNAL for November, 1922, was used to determine the condenser kv-a. necessary and the line and transformer losses under different conditions of load. Fig. 13 gives the diagram for the 1,600,000-cir. mil aluminum cable and Fig. 14 gives the condenser kv-a. necessary for different sizes of aluminum and copper cables under various loads. In order to determine the most economical conductor, it is necessary to find the one for which the sum of the variable costs are at a minimum under any stated condition.

These variable costs were determined and put in the form of annual cost per kilowatt year delivered. The different items making up the variable costs consisted of the annual depreciation and interest on the condensers, cable and towers, together with the annual cost of energy wasted in the transmission circuit which includes the transformers and condensers, as well as the line itself.

The cost of energy lost was determined by the cost of reproducing it by steam at the same load center,

TABLE I
AUXILIARY CONSTANTS

Circular Mils....	600,000	650,000	800,000	950,000	1,000,000	1,600,000
Material....	Aluminum	Copper	Copper	Copper	Aluminum	Aluminum
Diameter..	0.96 in.	1.1176 in.	1.031 in.	1.123 in.	1.24 in.	1.544 in.
A.........	0.858 / 1deg.18min.	0.857 / 1deg. 7min.	0.859 / 0deg.46min.	0.857 / 0deg.49min.	0.857 / 1deg. 8min.	0.855 / 0deg.49min.
B.........	236 /80deg.14min.	229 /83deg.37min.	232 /85deg. 5min.	229 /85deg.22min.	227 /83deg.32min.	220 /85deg.31min.
C.........	0.001136 /90deg.29min.	0.001163 /90deg.18min.	0.00115 /90deg.47min.	0.001177 /90deg.18min.	0.001184 /90deg.18min.	0.001238 /90deg.12min.

taking into consideration the annual load factor. The variation in cost of towers, due to the use of different size conductors was determined by the economical study of tower design given in another part of this paper.

Fig. 15 gives the comparative variable costs per kilowatt year for different loads and different sizes of

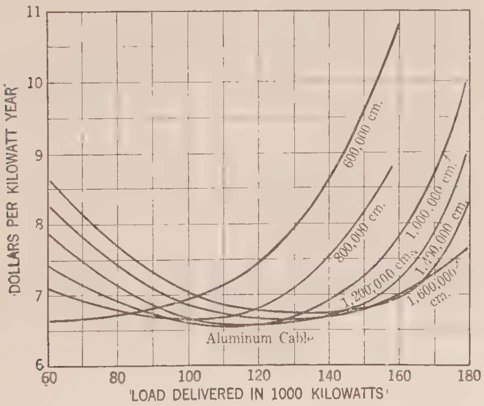

FIG. 15

aluminum conductor. Fig. 16 gives the same thing for copper conductors.

An analysis of the curves shows that 150,000 kw. is the maximum economical load, since the annual costs start to increase either before or at that point even on as large a cable as 1,600,000 cir. mils. There are several

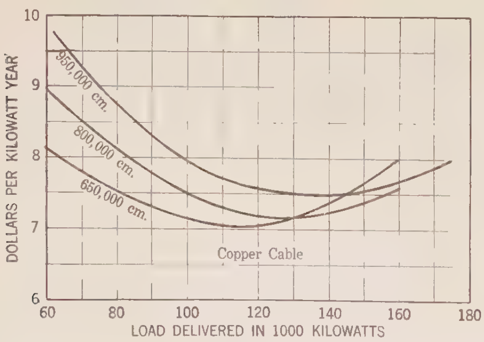

FIG. 16

sizes of conductors where the cost curve is comparatively flat between 100,000 kw. and 150,000 kw. delivered.

The curves also show that there is no clear-cut decision available as to the correct size of cable. Before the final decision is made consideration must be given to several factors. For instance, the prices upon which the curves are based are those of the early spring of 1924 and are subject to revision, the total initial cost may be a deciding factor and the load conditions under which the line will operate also affects the answer.

Section 4—Vibration of Conductors and Overhead Ground Wires

BY J. M. GAYLORD

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Among the problems connected with the 220-kv. lines, that of the vibration of conductors and ground wires has claimed its share of attention. On account of the larger diameter of the conductors this phenomenon is clearly visible, and exaggerated reports are frequently received that the conductors are jumping up and down 6 in. or more. There have also been complaints of the rattling of towers, even on still nights. In one instance a conductor failed at the outer end of a dead end clamp and the appearance of the broken strands indicated that vibration might have caused the break. A second conductor was discovered with 28 aluminum strands out of a total of 54 broken at the end of a dead end clamp. Numerous cases of broken ground wires have been found, the strands breaking at the point of attachment to the towers. In a few cases ground wires have fallen but a larger number of broken strands has been discovered by inspection and repaired before complete failure of the cable. These troubles led to an investigation of the vibration problem as it appears in the spans of the Big Creek and Eagle Bell lines. While this investigation has not yet led to definite conclusions as to the cause of vibration and method of preventing it, the information obtained is presented here as a part of the operating record.

The motion of the conductors is always in an approximately vertical plane and no horizontal displacement of the conductor has been observed. It is comparatively easy to secure records of the amplitude, frequency and duration of the vibrations. This is done by means of the recorders shown in Fig. 17. The motion is transmitted to the recorder by means of a paraffined string thrown over the conductor and attached to the sliding block, which carries the pencil. A spiral spring below the sliding block keeps the string taut. For the frequency records the paper is moved horizontally by hand, the motion being timed with a

stop watch. The 24-hr. duration records are obtained by applying a similar device to the circular record chart of a Bristol mechanical recorder. Simultaneous records of vibration and temperature were taken to determine a possible relation between these conditions. These records fail to show any such

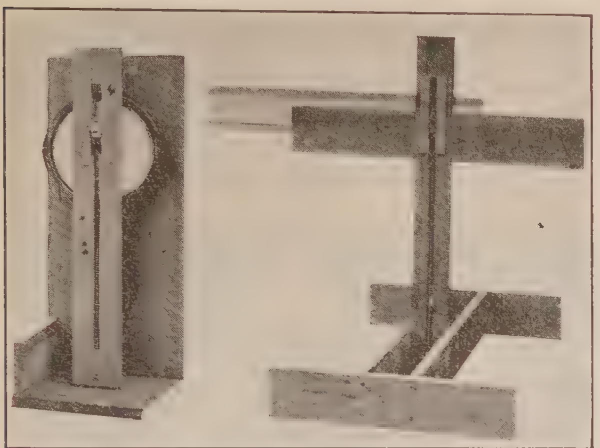

Fig. 17

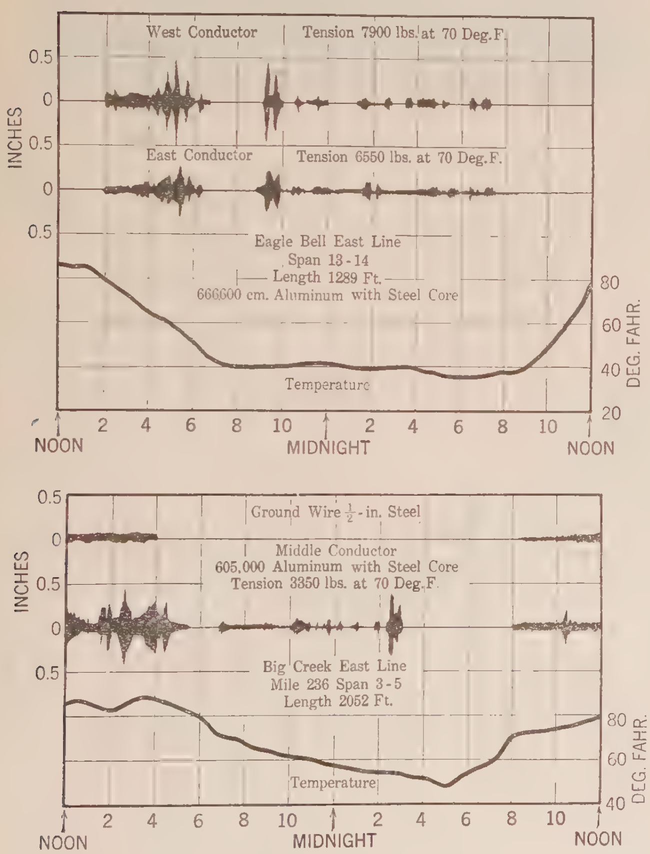

Fig. 18

relation and appear to establish the fact that vibration is generally independent of temperature. A great many spans apparently never vibrate while some are particularly subject to vibration; the longer spans being particularly susceptible. Vibrations are intermittent and the records show that they start and stop at irregular intervals throughout the day. Fig. 18 shows typical records of amplitude and duration. These graphs were transcribed from the original records to eliminate the effect of the stretch of the string which makes an irregular line on the circular chart and obscures the meaning of the record.

Spans subject to vibration were observed under various conditions, such as the sudden changes of temperature, lines dead, lines being energized, lines being dropped, etc., and it appears that vibration is not effected by any of these changes. Apparently this is a purely mechanical phenomenon and might have been encountered on lines of any voltage just as well as on the 220-kv. system.

In span 13-14 of the Eagle Bell line vibration is

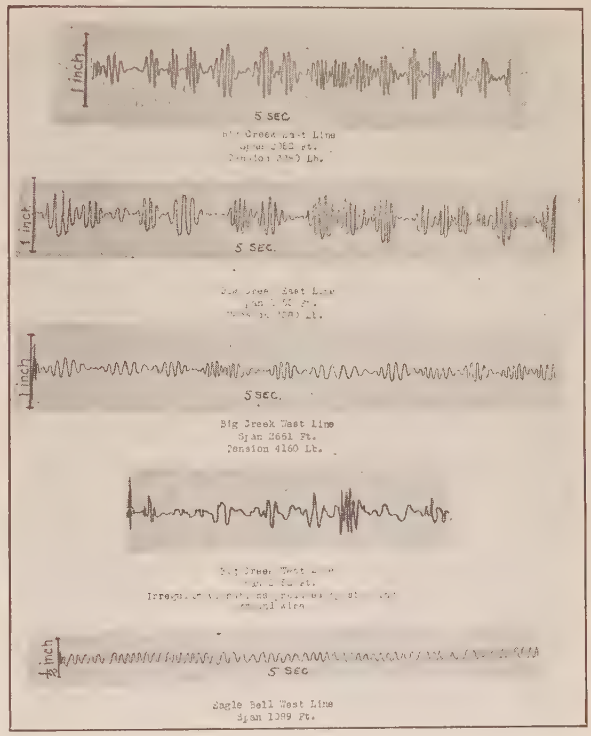

Fig. 19

especially prevalent and it was at this point that one conductor failed. When temporary repairs were made, this conductor was left with considerably less tension than the others. Simultaneous records were taken of the tight and loose conductors in this span and both were found to vibrate during approximately the same periods throughout the day, although the amplitude and frequency were less in the loose conductor. Apparently conditions other than tension and temperature produce the vibrations. There appears to be no difference between center and outside conductors on the tower as far as vibration is concerned. Several simultaneous records show practically the same periods of vibration for each position.

Fig. 19 shows typical records of frequency, character and amplitude of vibration. Some of the records show

simple vibrations of a single frequency, while in others various lower frequency components are present. Amplitudes as great as 1 in. were observed, while frequencies varied from 13 to 30 cycles per second in the spans tested. Standing waves 12 to 16 ft. in length were found in most cases where vibration was present. The normal sustained vibrations are regular in frequency and character and this quality appears to be essential to maintaining the vibration of the conductor. Attempts to set-up vibrations in the ground wire by striking it with the hand resulted in irregular vibrations which soon died out.

Vibration is believed to be due to air currents. Strong winds do not usually produce vibration but appear to have the effect of damping out the oscillations by setting up swaying motions of the wires. A slight air current appears to be sufficient to start and sustain the vibrations.

Means of preventing vibrations are still under consideration. It seems probable that an irregularity in the weight of the conductor might tend to damp out the vibrations and such a plan has been considered. Weighting of the conductor at various points might accomplish the same result. However, the places most affected by vibration are at dead end clamps and other points where the waves are reflected, and there is objection to increasing the number of such points by clamping weights to the conductor. The most violent cases of vibration have been noted in spans which have been in service for 10 years or more and the fact that no failures have occurred in such spans indicates that vibration alone is not much to be feared. The suspicious failure of steel reinforced aluminum occurred in the Eagle Bell line where the mechanical stress is higher than in the older line, and it seems probable that high stress combined with vibration is liable to cause trouble. However, the evidence is not conclusive as to how much the vibration would contribute to the failure.

The most promising method of preventing the damage due to vibration at points of reflection appears to be to provide a joint where movement can take place without bending or shock to the cable, and new clamps have been designed with this in view. Fig. 20 shows a new cast aluminum dead-end clamp which is being tested. The mass of the clamp has been reduced to a minimum so that it will move about its supporting pin, vibrating as a part of the conductor instead of reflecting the waves from its outer end by reason of its inertia. Simple mechanical devices are provided for holding the aluminum strands and steel cores. The aluminum is held by the standard compression joint which has proven by long service to be electrically and mechanically good. The steel core is held separately by long taper conical wedges which have been tested to the ultimate strength of the core. Several other improvements are embodied in the design. Cast aluminum terminals are attached to the jumpers by means of compression joints and a plain bolted connection is made between the jumper terminal and dead end clamp. This arrangement eliminates the troublesome process of bringing out the aluminum strands separately at the side of the clamp for attaching the jumper, and the more or less uncertain bolted clamps for splicing the jumper. Ample current capacity is provided in the cast aluminum body of the clamp and current-carrying connections are all made with the standard compression joint or by means of flat bolted surfaces. This clamp has been installed on an experimental span and will be tested to determine its performance under vibration conditions duplicating those on the line.

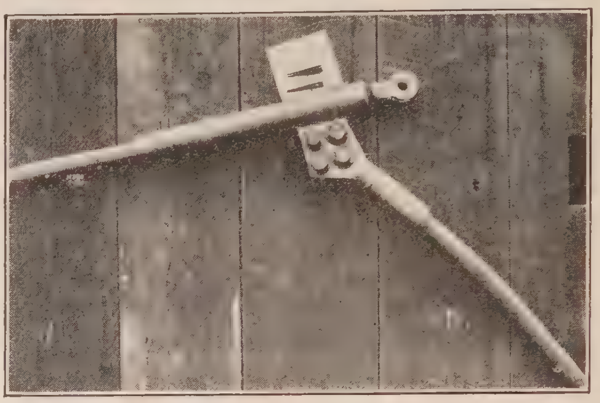

Fig. 20

Section 5—Location and Right of Way

BY V. D. ELLIOTT
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Transmission line location is an art which has been somewhat neglected as compared to other branches of the electric utility industry, or, as compared to railroad or highway location. This has come about in a natural way because transmission lines in the beginning were comparatively cheap affairs and even with the advent of steel tower construction and higher voltages the cost per mile was far below that of a railroad or well constructed highway. Often much time and engineering skill were expended on power houses, dams and pipe lines and even on transmission line design, but the location and construction of the line were put off until the last moment and then rushed through in a haphazard fashion with resultant losses.

The cost of 220-kv. circuits on separate parallel lines of towers, such as the recently constructed Eagle Bell line, is in the same class with that of a railroad or highway, hence the business of selecting and securing a right of way is worthy of considerable thought and careful balancing of all factors involved. Many points which are of minor consideration on lower voltage lines become of real importance on the 220-kv. line.

In choosing a location for the Eagle Bell line and for a new line to Big Creek, known as the Vincent Line,

which is still in the process of being located, the same general methods that are applicable to any transmission line location work have been used but with modifications or refinements which will be described.

In rough or mountainous country the controls are the natural topographic features and the main points to be borne in mind are safe and suitable locations for towers and a general alignment such that material may be delivered by motor truck via existing roads, or such that new roads can be built without too great an expense. With high tonnage of material and men to be delivered, this becomes a very important item and must be given more consideration than with smaller lines.

In flat or agricultural lands the controls are all artificial or man-made and influence the right-of-way cost.

The final choice of location must usually rest on reconnaissance work which proceeds the actual line survey. This reconnaissance is therefore a very important part of the job and holds great possibilities for saving or spending money unnecessarily on construction or right-of-way purchase.

The problem naturally divides itself into the two classifications previously indicated, *viz.*, the case of rough or mountainous country of little or no commercial value and the case of relatively flat, tillable land highly developed with crops, highways, railroads and farm or residential buildings where land values are high and natural topographic features of little or no importance. There are, of course, gradations between these two extremes in which may be included land of low commercial value possessing no controlling topographic features. In this case no problem exists and a straight line is laid out.

A portion of the Eagle Bell line is located on a right-of-way 250 ft. wide, in a highly developed territory near or within incorporated city limits where land values range from $2,000 to $5,000 per acre. Areoplane reconnaissance was found to be a very valuable help and aerial maps of this territory were particularly useful in projecting the line among improvements to the best advantage and buying parcels of land or negotiating for a strip without the inevitable advertising resulting from a survey. It should be understood that useful as these maps and aeroplane reconnaissance were, they did not reduce the amount of final survey work necessary nor entirely eliminate ground reconnaissance. The actual saving, due to the speed and accuracy with which the purchases proceeded, cannot, of course, be determined but all indications are that it was many times the cost of the maps.

A location through land of this character giving minimum total cost resulted in a very crooked line.

Aeroplane reconnaissance over mountains or hilly lands gives one a comprehensive general view and impression which cannot be secured in any other way. At a height of from four thousand to six thousand feet above the ground details are visible in good weather but the topographic features assume their proper proportions and relations to one another so that important ones stand out and produce the proper impression on the mind of the observer. When observing from a high point on the ground, part of the terrain is hidden from view and a certain distorted impression is gained due to the different distances from the eye of the various features in the range of vision.

Despite this defect in ground observation it is a necessary supplement to the aeroplane view in choosing a final location. In addition to this preliminary or trial lines are often justified. These may ordinarily be run by stadia and only the major controls or those of especial bearing on the question taken. While a profile of this kind does not accurately represent the country, it is a great aid and will usually contain enough information to enable one to make an intelligent choice between two or more alignments. When it is considered that the cost of one tower is equal to the cost of several miles of such preliminary line the wisdom of this refinement is evident.

Experience with aerial maps of mountainous territory show them to be difficult to produce with satisfactory accuracy and to be of little benefit. Dangerous and adverse flying conditions and scale distortions, due to uneven ground elevations, multiply enormously the cost and mechanical difficulty of producing accurate maps and the information conveyed concerning relative elevations and other controlling topographic features is so meager that their cost cannot be justified.

Having chosen a final alignment, a survey must be made which will show to a predetermined accuracy the horizontal and vertical distances between points on the line and also the relation of the line to property corners and legal subdivisions of land. This last is, of course, purely for right-of-way purposes. This general statement regarding survey is true of a transmission line of any voltage but with the 220-kv. line, the cost and importance of it justifies methods of survey which will give a higher degree of accuracy and are less likely to contain errors than those frequently used.

Two methods have been tried thus far. In the first case, conditions were ideal for choosing an alignment, setting signals on probable tower locations and tying these points into a triangulation system from base lines conveniently located. Stadia topography was taken in the vicinity of the probable tower points and at points of doubtful clearance in between. No center line profile was run but one was plotted from the topography. In the second case, a center line profile was taken by means of slope chaining in the roughest country and horizontal chaining with a line of levels where the country was not so rough. While the triangulation method with local topography worked out fairly well where it was used, the second method appears to be better and of more general application.

The Eagle Bell right-of-way is intended to accommodate three tower lines of horizontal construction, the towers being 78 feet apart, center to center. The right-of-way is 250 feet wide and with a conductor spread of 22 ft. 3 in. leaves only 24 ft. 9 in. from the outside wire to the edge of the right-of-way. With a calculated conductor swing of 18 ft. 6 in. in the normal span, a clearance of 6 ft. 3 in. remains to the edge of the right-of-way. This is not all that could be desired but on the high priced land this was considered the maximum permissible width. On public lands in the National Forest and private lands of lower value a 300-foot right-of-way was secured. On the new Vincent line to Big Creek a 200-foot right-of-way is being secured to accommodate two tower lines.

Projecting and securing a right-of-way as wide as this becomes a real problem, not only because of the acreage involved but also on account of the difficulty of finding wide enough spaces between obstructions.

On the Eagle Bell line the right-of-way was purchased in fee. Due to its proximity to cities and towns and rapidly developing territory this was considered a wise precaution in order to make the position of the line more secure. With a right-of-way this width it is practically necessary to purchase in their entirety small land parcels which are hopelessly cut up by such a strip. The left-over pieces can, however, be grouped together or rearranged and sold to advantage when they are under one ownership. This was done on the Laguna Bell line and, due to the rising real estate market, showed a profit in many cases.

On the Vincent Line, easement is being secured except for a few cases where fee is being purchased for the same reasons as on the Eagle Bell line. The protective clauses in the easements are more effective than usual and for the class of territory traversed easements are believed to be adequate.

The best job of right-of-way location and survey work may be set at naught by careless or injudicious location of towers and special effort should be made to insure that this part of the work be accurately and carefully done. The old reliable centerline profile and celluloid template of wire curve are found to operate on 220 kv. as well as on 60 kv., but due to the wide spread of the conductors, it is necessary to take account of the cross slope of the ground at critical places to a greater extent than with the lower voltage. This is especially true of single-circuit horizontal construction in which the spread is greatest.

The experience in tower locating on the Eagle Bell line showed that in rough country the exact location of towers, as well as their elevation and type of extension, if any, must be determined on the ground. Reasonably good topography with a one-foot contour interval was found inadequate for properly locating towers, mainly because of soil or other conditions which could not well be shown on a map.

RADIO IN HOSPITALS

One of the most useful fields for radio is the reception of broadcasting in hospitals. Besides the benefit to patients through the entertainment provided, medical authorities testify to the actual therapeutic value of the mental relief thus afforded. The Bureau of Standards is assisting in the technical phases of current movements to equip many thousands of hospital beds with radio service. Since the middle of March of this year S. L. Rothafel, managing director of the Capitol Theatre, New York, N. Y., and his broadcasting artists have been raising funds for the installation of radio in the United States military service hospitals. A technical committee of Government experts (representing the Signal Corps, Navy Department, and Bureau of Standards) is furnishing technical advice as to the material and method of installation for these hospitals. The first hospitals equipped were Walter Reed General Army Hospital, Naval Hospital, and Mount Alto Veterans Bureau Hospital, all located in Washington, D. C.

The general system employed is to use one receiving set and a powerful amplifier to supply the entire hospital, each patient being provided with head telephone receivers which can be connected or disconnected at will. The amplifier used is capable of supplying about 3,000 headsets in parallel, and by reducing the number of headsets and using suitable transformers a number of loud speakers may also be used in the various rooms. At Walter Reed Hospital 1500 headsets and six loud speakers are used, the loud speakers being provided for assembly halls only. This equipment requires the services of one man continuously while the set is in operation to control the volume of sound delivered to the patients. The set used is capable of receiving distant as well as local programs, but because of disturbances that may be introduced in distant reception, local programs are used except on special occasions where a program of very general interest is being broadcast from a distant station. The installation includes a microphone which is used for the distribution to the patients of programs given in the auditorium or elsewhere in the hospital. This microphone makes it possible for any person to address all the patients of the hospital simultaneously. The installation has been in operation for four months and has been very satisfactory.

The work of equipping other hospitals is being continued and the material for all service hospitals in the vicinity of New York, N. Y., has been ordered. The aim of the movement is to make it possible for every patient in all the military hospitals of the United States to listen to radio programs. A large part of the money for this purpose has been raised and the campaigns are being continued. Similar campaigns for the equipping of nonmilitary hospitals in various places have been begun.

Sensitive Radio-Frequency Relay

BY GEORGE LEWIS
Non Member
Crosley Manufacturing Company, Cincinnati, Ohio

Review of the Subject.—*The present paper has been prepared with a view of describing the theoretical properties, mechanical construction, and possible application of a new electron relay, invented and developed by Samuel Ruben, a physicist of New York. This relay has been developed to control currents as great as 5 amperes by means of extremely small operating currents of any frequency, and its use is suggested, therefore, in radio and carrier-current systems, and where similar requirements are to be met.*

* * * * *

Principles of Operation

THE operation of this relay is primarily based upon the employment of the kinetic energy of the thermionic discharges brought about by a suitable emission element, such as a filament, when directed upon a sensitively responsive anode. The impact of the electron stream upon the anode results in the expenditure of the kinetic energy of the bombarding stream, which is translated as;

1. A slight and negligible mechanical effect,
2. A negligible radiation of low-wave length and
3. A temperature rise of the anode.

Various tubes have been constructed by Mr. Ruben, in which he has employed different anodes for the utilization of the thermionic bombardment principle. As the temperature rise of the anode is the major effect in this type of tube, amounting to practically the entire translation of the kinetic energy of the electron stream, the anode adopted as the most serviceable is the thermo-sensitive type. (Figs. 1 and 2).

In the type of tube described in this paper, the translated energy is employed as a means for operating the contacts of a relay located within the tube.

The rapidity of the action of this device is dependent on the rate of heating and the rate of cooling of the anode, which, in turn, are dependent upon factors as follows:

Rate of heating—dependent on:

(a) Power of bombarding electrons—this should be as great as possible.

(b) Heat capacity of anode—this should be as small as possible.

Rate of cooling—dependent on:

(a) Ability of anode to radiate power.

(b) Heat capacity of anode—this should be as small as possible.

In the device as now developed, the anode is composed of a blackened strip of nichrome which is initially maintained at a high temperature, in the neighborhood of 600 deg. cent. The strip form gives a large radiating surface with a small mass and therefore small heat capacity. The high initial temperature gives the anode increased ability to radiate power, since this depends on the fourth power of the temperature.

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chiacgo, Ill., June 23-27, 1924.

This relay comprises four main elements:

1. A source of electron emission—a cathode,
2. A means for controlling the electron emission flow,
3. A sensitively responsive anode, and
4. A movable contact arm and a stationary contact for the control of a high-density external circuit.

The cathode element employed in this relay is a platinum-iridium strip having a newly-developed oxide coating which gives the cathode a high thermionic

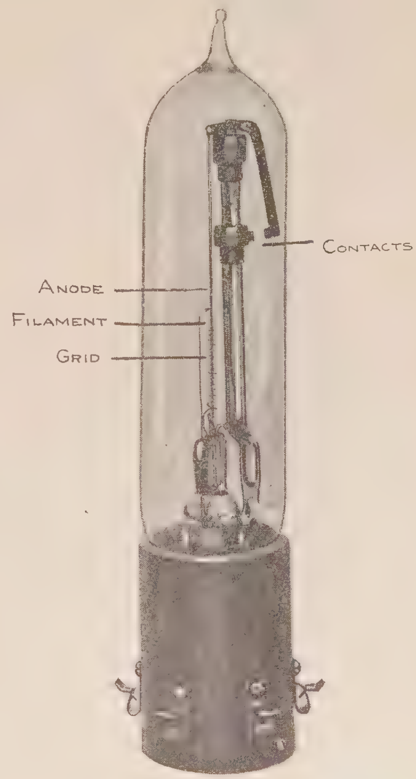

Fig. 1

efficiency and a long life. The strip is suspended parallel to the sensitively responsive anode, which is composed of nichrome, attached at one end to the movable contact arm of the make-and-break device, controlled by the movement of the anode responding to the impact of the electron stream upon it. The electron discharge from the filament is electrostatically controlled by a grid element interposed between the filament and anode, so that in operation the grid

controls the anode movement by virtue of its control of the electron stream.

The anode is maintained by a local circuit at a temperature at which the movable contact is normally at a point very minutely spaced from the stationary contact. Such close contact spacing, without any tendency to arc or spark, even when the external circuit carries a current of considerable potential, is made possible by the degree of evacuation to which the tube is subjected before the sealing-off process is completed.

As the necessary slight movement of the contact arm ot the make-and-break device is controlled by the thermo-expansive anode of the described characteristics, the operating speed of the device is high compared with usual thermal devices.

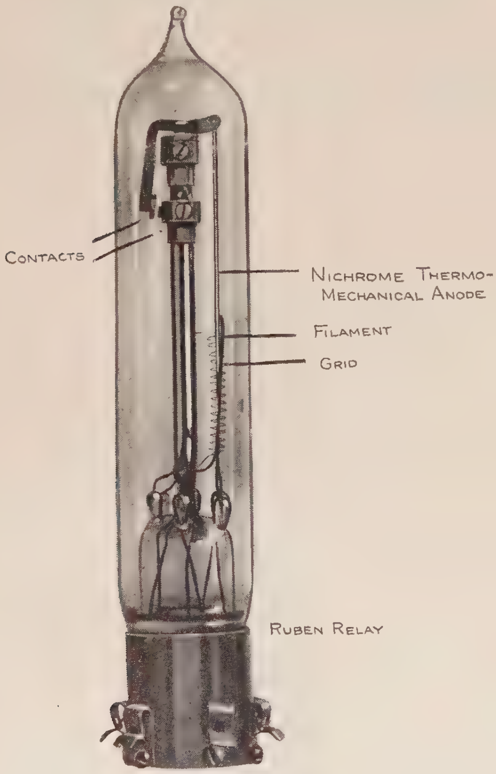

FIG. 2

To avoid any deformation of the elements of this device from the repeated application of high temperatures, especially in the process of evacuation, great care has been taken in their composition and design. The result is a notable stability of adjustment under operating conditions.

Nichrome was selected for the anode as it was found to possess the following desirable electrical and physical characteristics:

a. Operating constancy over long and interrupted periods of use,

b. High and constant values of electrical resistance at various operating temperatures,

c. Suitable coefficient of expansion and

d. Adequate mechanical strength at operating temperatures.

The contacts of the circuit control device are composed of tungsten, one being affixed to a lever supported for the proper ratio of its arms. The lever and stationary contact support are composed of nickel-manganese, an alloy found suitable for vacuous devices. One end of the lever carries the tungsten contact, and the other is attached to the thermo-expansive anode. As the anode expands and contracts in response to the action of the controlling electron stream, the movable contact moves towards and away from the stationary contact, thus serving to close and open the external circuit.

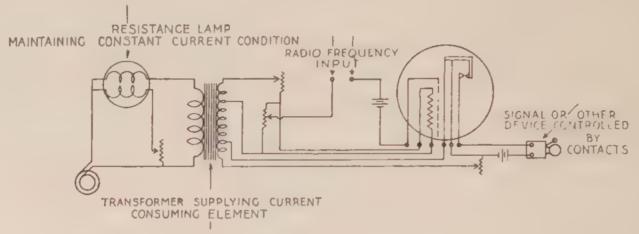

FIG. 3

The normal position of the lever can be made practically independent of the position of the apparatus itself, which can be mounted in a horizontal or vertical plane.

The actual energy necessary to control the external circuit of high density is of very small magnitude, being only that necessary to electrostatically charge the grid element sufficiently to modulate the impacting electron stream, as in the present thermionic devices. The time required for the actuation of the lever is controlled by the heating current normally discharged through the anode.

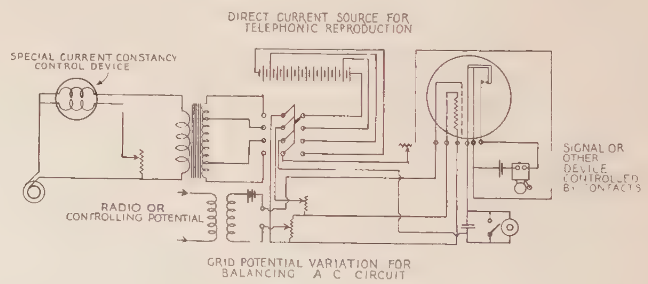

FIG. 4

CONNECTION OF RELAY IN CIRCUITS

Fig. 3 shows a typical connection of such a relay into a circuit. In the circuit as shown the relay is operated by incoming radio signals, and controls a signaling device indicated as a call bell. The anode is so connected that its energizing circuit is partially short-circuited when the contact of the relay circuit is

closed, thus causing the anode to cool by radiation, and causing the circuit to open. By this rapid heating and cooling of the anode element the relay contact opens and closes the external circuit at a rate of about 20 times per second.

The relay can be employed in this manner as a call device for radio or carrier-wave circuits for either telegraphy or telephony. When used in this manner, all of its circuits can be supplied with energy from a single transformer as indicated.

To keep the adjustment constant and independent of line variations, a ballast lamp specially developed for this relay has been supplied. The lamp comprises two resistance elements in a hydrogen filled tube, one element being iron, which controls a current flowing to the primary of the transformer, and operated at about 500 deg. cent. at which temperature iron has an exceedingly large resistance temperature coefficient. The other element is nichrome wire which is directly connected across the line; its temperature is adjusted by means of an external resistance to bring the controlling iron resistance element to a proper temperature. When adjusted, large variations in the line potential are compensated and the relay adjustment is stable.

Fig. 4 shows the same circuit with a change-over switch to allow the use of telephone receivers in the plate circuit, by which a call-signal relay and an audio-frequency relay in one tube are obtained.

This relay can be connected in a circuit as a reflex, a regeneration or an amplification tube, or in any connection in which the usual three-element tube is applicable, with the added advantage of the local circuit control of current of high density or high potential.

In conclusion, it may be stated that the Ruben relay has been designed to obtain a relay which could be controlled by minute energies in the form of currents of any frequency, either radio or otherwise, could be operated at adequate speeds for certain telegraph applications, and could control circuits of considerable current and potential. Its application is suggested for any conditions where these requirements are to be fulfilled, such as radio and carrier calling and recording systems, as a telegraph recorder and repeater, either line or cable, and for similar purposes.

HIGH FUEL COSTS COMPEL HYDRO-ELECTRIC DEVELOPMENT

Electrical engineers in Germany are being forced by the high price of coal to utilize the nation's water-power resources to the fullest extent. The first hydro-electric plant in the Province of Brandenburg, located at Spremberg, started operating this year. The satisfactory results obtained have led to a survey of other possible power sites in this province and favorable places have been discovered at Wendisch-Buchholt, at Boden near Deichow, and at Lausitzer Neisse near Forst. The intentions are that work will be started on these plants as soon as economic conditions in Germany permit.

CORRESPONDENCE

THIRD RAIL FOR STEEL YARDS

To the Editor: I note with interest the report of the Iron and Steel Industry Committee as set forth in the JOURNAL of the A. I. E. E. for October, 1924, and am particularly interested in Item III covering yard electrification.

I agree with the Committee, in general, in the economies which they have developed for electric operation as compared with steam. I am, however, taking this opportunity to differ with the Committee in its statement regarding the getting of power to the locomotive.

I believe all steam railroad men who have had experience in yard switching are agreed that a third rail in a large and complicated yard is extremely undesirable. Even though the third rail is of the under-running type and protected against electrical contact, nevertheless, mechanical complications in the location of the third rail are extremely serious and dangerous to life and limb. These difficulties are entirely eliminated in overhead power distribution.

In highly congested yards where there are large numbers of switches, crossovers, etc., the operation by means of the third rail is practically impossible on account of the gaps which must necessarily be left in the contact unless the use of an overhead third rail at such points is resorted to.

SIDNEY WITHINGTON

To the Editor: Mr. Withington's comments on the report of the Iron and Steel Industry Committee as contained in our copy of his letter to you dated October 9 leaves little opportunity for a difference of opinion. In his third paragraph he states "all steam railroad men who have had experience in yard switching are agreed that a third rail in a large and complicated yard is extremely undesirable." The report of the Iron and Steel Industry Committee takes no exception to that statement.

It should be borne in mind, however, that in the first place, the report of the Committee deals only with the electrification of steel plant yards, which in no case are "large and complicated" in the sense in which Mr. Withington uses the terms. The electrification of the steel yard is less of a problem than the electrification of the usual railroad yard. The third rail system is obviously open to the objections mentioned by Mr. Withington; yet, on the other hand, the extensive use of locomotive cranes with lifting magnets or grab buckets renders the use of an overhead system at least equally unsatisfactory from the standpoint of personal danger from the operating difficulties. A careful reading of the report will show that the tendency in steel plant yard electrification is toward the use of self-contained electric locomotives of the storage battery or Diesel-engine-generator types.

FRED B. CROSBY.

The Direct Method of Calculation of Capacitance of Conductors

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Review of the Subject.—*The capacitance, or electrostatic capacity, of conductors of various shapes has practically always been calculated by the "inverse method" of first assuming certain charges of electricity and from them calculating equi-potential lines and surfaces, which, in the more fortunate cases, agreed exactly with the shapes of the conductors. In other cases, such as that of a three-conductor sheathed cable, the agreement, and therefore the calculated capacitance, were only approximate.*

For multi-conductor cables with round conductors, a "direct method" of calculation of capacitance is described in this paper, which uses the exact shape of the round conductors, and which gives accurate expressions for the irregular distribution of electricity on the conductors, and for the value of the capacitance.

Formulas and examples are given for the following cases: 1. Finite wire and infinitesimal wire. 2. Single-phase overhead line. 3. Two conductors and sheath. 4. Three conductors and sheath.

THE direct method of calculation of capacitance, as distinguished from the more usual inverse method, consists in first assuming the shape of the conductors, and from that calculating the distribution of electric charge and the capacitance. In the inverse method, one finds the shape of the conductors from the potential calculated from charges of electricity concentrated at points or uniformly distributed along lines or over surfaces. If the equi-potential lines are not true circles, then the calculated capacitance is not correct for circular conductors, but is only approximate. This is the case with two-conductor and three-conductor sheathed cables.

In this paper, accurate formulas using the direct method are given for four cases: first, a finite wire and an infinitesimal wire; second, the capacitance of a single-phase overhead line; third, the capacitance of the sheath on one side and the two conductors on the other side, of a two-conductor cable; and fourth, the capacitance of the sheath on one side and the three conductors on the other side, of a three-conductor cable. For the second case an accurate standard formula is available for comparison. The formula for the third case, given in this paper, was given by the writer in a discussion in the JOURNAL of the A. I. E. E., November, 1923, page 1208.

It appears that practically all formulas for capacitance have been based on the inverse method. This is true, at any rate, of the published formulas for capacitance of multi-conductor sheathed cables. It is stated by Clerk Maxwell in Chapter VII of "Electricity and Magnetism," published in 1873, that every electrical problem of which we know the solution has been constructed by the inverse process of finding the shape of the conductors from the potential due to assumed charges of electricity. He also states that the only method by which one can expect to solve a new problem is by reducing it to one of the cases in which a similar problem has been constructed by the inverse process. Maxwell's statement has been quoted in fairly recent articles, and the limitation which he gives that the inverse process must always be used and that one cannot start with an assumed shape of conductor seems to hold in the most recent calculations of capacitance. It seems evident that the direct method described in this paper, which accurately uses the direct process of starting with given shapes of conductors, should be of considerable use.

The demand for greater accuracy in this type of calculation is shown by the paper published by Mr. D. M. Simons,[1] who gave results for two, three and four-conductor cables which are more accurate than those previously available obtained by the inverse process of calculation. Mr. Simons' results were obtained by graphically correcting the length of the lines of flow pertaining to the inverse method of calculation. His results still contain a certain amount of approximation as was pointed out in his paper, since the position of the lines of flow is not that corresponding to true circular conductors, and that accounts for some of the discrepancy between his results and those given in this paper.

In connection with the calculation of the numerical example of the three-conductor cable given in this paper, the writer wishes to acknowledge valuable assistance given by Mr. D. M. Simons in checking and locating errors in the preliminary work.

In the direct method of calculation of capacitance described in this paper, one first assumes a uniform electric charge on the surfaces of the round conductors and their images. From this the resulting charge at any point of the conductors can be calculated. This may be called the first additional charge, and it is in the form of a Fourier series, that is, a series involving $\cos\theta$, $\cos 2\theta$, $\cos 3\theta$, etc. The cosines often disappear when integrated around the circle. One can now calculate the second additional charge, which results from the first additional charge, and so on until the terms become small.

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

1. "Cable Geometry and the Calculation of Current-Carrying Capacity," by D. M. Simons, JOURNAL A. I. E. E., May, 1923, page 525.

Finite Wire and Infinitesimal Wire

This is not a practical case, but the solution is used in the problems to follow.

Let there be a finite wire A, carrying an electric charge Q per centimeter, and let there be an infinitesimal wire B carrying an electric charge $-Q$ per centimeter. Quantities are in absolute units. Let O be the point of zero potential.

The surface density of the charge on A will not be uniform, owing to the presence of the charge on B. From the symmetry of the arrangement, the surface density $q_{(\theta)}$ at any point P can be expressed as a Fourier series, the angles being measured from the line $B\,D$. Thus

$$q_{(\theta)} = H_0 + H_1 \cos\theta + H_2 \cos 2\theta + \ldots + H_n \cos n\theta + \ldots$$

where H_1, H_2 etc. are undetermined constants. The total charge on the wire A is

$$\int_0^{2\pi} q_{(\theta)}\, a\, d\theta = 2\pi a H_0 = Q$$

Therefore, $$H_0 = \frac{Q}{2\pi a}$$

The work done against the elementary charge $q_{(\theta)}\, a\, d\theta$ at P, in carrying a unit charge from O to N is

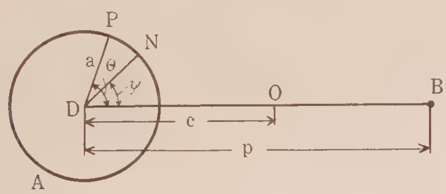

Fig 1—Finite Wire and Infinitesimal Wire

$$2\, q_{(\theta)}\, a\, d\theta \operatorname{logh} \frac{O\,P^*}{N\,P} \qquad (1)$$

The work done against the charges on both conductors is

$$-2\,Q \operatorname{logh} \frac{O\,B}{N\,B} + 2\,a \int_0^{2\pi} q_{(\theta)} \operatorname{logh} \frac{O\,P}{N\,P}\, d\theta \qquad (2)$$

The following expansions are now required:

$$\operatorname{logh} \frac{N\,B}{p} = -\left\{ \frac{a}{p}\cos\varphi + \frac{a^2}{2\,p^2}\cos 2\varphi + \ldots + \frac{a^n}{n\,p^n}\cos n\varphi + \ldots \right\} \qquad (3)$$

$$\operatorname{logh} \frac{N\,P}{a} = -\left\{ \cos(\theta-\varphi) + \frac{1}{2}\cos 2(\theta-\varphi) + \ldots + \frac{1}{n}\cos n(\theta-\varphi) + \ldots \right\} \qquad (4)$$

*Elements of the Mathematical Theory of Electricity and Magnetism, by J. J. Thomson, fourth edition, page 94.

$$\operatorname{logh} \frac{O\,P}{c} = -\left\{ \frac{a}{c}\cos\theta + \frac{a^2}{2\,c^2}\cos 2\theta + \ldots + \frac{a^n}{n\,c^n}\cos n\theta + \ldots \right\} \qquad (5)$$

The derivation of the last series, which is similar to that of the others, is as follows:

$$O\,P^2 = c^2 + a^2 - 2\,a\,c\cos\theta$$

$$\frac{O\,P^2}{c^2} = 1 - a/c\,(e^{j\theta} + e^{-j\theta}) + a^2/c^2$$

$$= (1 - a/c\;\, e^{j\theta})\,(1 - a/c\;\, e^{-j\theta})$$

$$2 \operatorname{logh} \frac{O\,P}{c} = -\left\{ \frac{a}{c}\, e^{j\theta} + \frac{a^2}{2\,c^2}\, e^{2j\theta} + \ldots + \frac{a^n}{n\,c^n}\, e^{nj\theta} + \ldots + \frac{a}{c}\, e^{-j\theta} + \frac{a^2}{2\,c^2}\, e^{-2j\theta} + \ldots + \frac{a^n}{n\,c^n}\, e^{-nj\theta} + \ldots \right\}$$

from which equation (5) follows directly. Series (3), (4) and (5) are used in calculations of proximity effect in conductors.

Equation (2) can now be written: Work in moving a unit charge from O to N

$$= 2\,Q \operatorname{logh}\left(\frac{p}{p-c}\right) - 2\,Q \left\{ \frac{a}{p}\cos\varphi + \frac{a^2}{2\,p^2}\cos 2\varphi + \ldots + \frac{a^n}{n\,p^n}\cos n\varphi + \ldots \right\}$$

$$+ 2\,a \int_0^{2\pi} \left[q_{(\theta)} \operatorname{logh} \frac{O\,P}{c} - q_{(\theta)} \operatorname{logh} \frac{N\,P}{a} + q_{(\theta)} \operatorname{logh} c/a \right] d\theta \qquad (6)$$

where $$q_{(\theta)} = \frac{Q}{2\pi a} + H_1\cos\theta + H_2\cos 2\theta + \ldots + H_n \cos n\theta + \ldots$$

Now $$\int_0^{2\pi} \cos m\theta \cos n\theta\, d\theta$$

$$= 1/2 \int_0^{2\pi} \{\cos(m+n)\,\theta + \cos(m-n)\,\theta\}\, d\theta \qquad (7)$$

This is equal to zero when m is not equal to n and it is equal to π when $m = n$. Thus, in multiplying one series by another in (6), most of the terms are equal to zero.

Work in moving a unit charge from O to N

$$= 2\,Q \operatorname{logh}\left(\frac{p}{p-c}\right) - 2\,Q\left\{\frac{a}{p}\cos\varphi + \frac{a^2}{2\,p^2}\cos 2\,\varphi + \ldots + \frac{a^n}{n\,p^n}\cos n\,\varphi + \ldots\right\}$$

$$+ 2\,\pi\,a\left[-H_1\frac{a}{c} - H_2\frac{a^2}{2\,c^2} - \ldots - H_n\frac{a^n}{n\,c^n} - \ldots + H_1\cos\varphi + H_2\frac{\cos 2\,\varphi}{2} + \ldots + H_n\frac{\cos n\,\varphi}{n} + \ldots + 2\frac{Q}{2\,\pi\,a}\operatorname{logh}\frac{c}{a}\right]$$

This is true for any value of φ, since the potential is constant for all points on the surface of the conductor, and so the coefficients of $\cos\varphi$, $\cos 2\,\varphi$, $\cos n\,\varphi$ etc. can be separately equated to zero. Therefore,

$$H_1 = \frac{Q}{\pi\,a}\,a/p$$

$$H_n = \frac{Q}{\pi\,a}\,a^n/p^n$$

$$q_{(\theta)} = \frac{Q}{2\,\pi\,a} + \frac{Q}{\pi\,a}\{a/p\cos\theta + a^2/p^2\cos 2\,\theta + \ldots + a^n/p^n\cos n\,\theta + \ldots\}$$

or
$$q_{(\theta)} = \frac{Q}{2\,\pi\,a} + \frac{Q}{\pi\,a}\sum_{n=1}^{n=\infty}\frac{a^n}{p^n}\cos n\,\theta \qquad (8)$$

This gives the distribution of the electric charge on the finite conductor, under the influence of a charge concentrated at B. This is a quantity required to be known for calculating capacitance in the problems described in this paper.

Single-Phase Overhead Line

The formula for this case is given to provide a check on the correctness of the direct method. The standard formula, derived by the inverse method, is shorter, and gives exactly the same numerical results.

Let there be two equal wires A and B and let one carry an electric charge Q per centimeter and the other a charge $-Q$ per centimeter. Then the density at P is $\frac{Q}{2\,\pi\,a}$ and at T it is $\frac{-Q}{2\,\pi\,a}$, assuming uniform distribution.

The density at P due to the elementary charge at T,

$$-\frac{Q}{2\,\pi\,a}\,a\,d\,\gamma$$

is

$$\frac{Q\,d\,\gamma}{2\,\pi}\times\frac{1}{\pi\,a}\sum_{n=1}^{n=\infty}\frac{a^n}{d^n}\cos n\,(\theta-\beta) \qquad (9)$$

Now

$$\frac{\cos n\,\beta}{d^n} = 1/s^n\left[1 + \sum_{k=1}^{k=\infty}\frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\,\frac{a^k}{s^k}\cos k\,\gamma\right] \qquad (10)$$

and

$$\frac{\sin n\,\beta}{d^n} = 1/s^n\sum_{k=1}^{k=\infty}\frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\,\frac{a^k}{s^k}\sin k\,\gamma\;* \qquad (11)$$

Integrate expression (9) from $\gamma = 0$ to $2\,\pi$, keeping θ constant. Then the density at P due to the uniform charge on wire B is

$$\frac{Q}{\pi\,a}\sum_{n=1}^{n=\infty}\frac{a^n}{s^n}\cos n\,\theta \qquad (12)$$

Let
$$A_n = a^n/s^n \qquad (13)$$

This is the first additional charge. A similar expression gives the first additional charge on wire B, namely,

$$-\frac{Q}{\pi\,a}\sum_{n=1}^{n=\infty}A_n\cos n\,\gamma$$

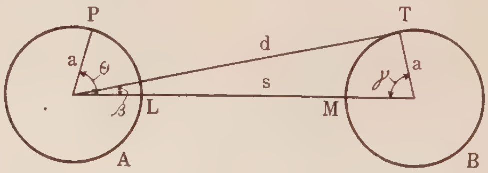

Fig 2—Single-Phase Overhead Line

The density at P due to the elementary charge at T,

$$-\frac{Q}{\pi\,a}\sum_{n=1}^{n=\infty}A_n\cos n\,\gamma\,a\,d\,\gamma$$

is
$$\frac{Q\,d\,\gamma}{\pi}\times\frac{1}{\pi\,a}\sum_{n=1}^{n=\infty}A_n\cos n\,\gamma\sum_{m=1}^{m=\infty}\frac{a^m}{d^m}\cos m\,(\theta-\beta)$$

Using equations (7), (10) and (11), and integrating from $\gamma = 0$ to $2\,\pi$, we find that the density at P, due to the first additional charge on wire B is

$$\frac{Q}{\pi\,a}\left[B_1\cos\theta + B_2\cos 2\,\theta + \ldots + B_n\cos n\,\theta + \ldots\right] \qquad (14)$$

where
$$B_n = a^n/s^n\left\{\frac{|\underline{n+1-1}}{|\underline{n-1}\;|\underline{1}}\,a/s\,A_1 + \ldots + \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\,a^k/s^k\,A_k + \ldots\right\} \qquad (15)$$

*"An Integration Method of Deriving the A-C. Resistance and Inductance of Conductors," by H. L. Curtis, Scientific Paper No. 374 of the Bureau of Standards, Washington D. C., April 1920, Appendix 2.

This is the second additional charge on wire A. Similarly, the third additional charge on wire A is

$$\frac{Q}{\pi a}\left[C_1 \cos\theta + C_2 \cos 2\theta + \dots + C_n \cos n\theta + \dots\right] \tag{16}$$

where $C_n = a^n/s^n \left\{ \dfrac{\underline{|n+1-1}}{\underline{|n-1}\,\underline{|1}}\, a/s\, B_1 + \dots + \dfrac{\underline{|n+k-1}}{\underline{|n-1}\,\underline{|k}}\, a^k/s^k\, A_k + \dots \right\}$ (17)

and so on. The total charge at P is

$$\frac{Q}{\pi a}\left[1/2 + L_1 \cos\theta + L_2 \cos 2\theta + \dots + L_n \cos n\theta + \dots\right] \tag{18}$$

where $\qquad L_n = A_n + B_n + C_n + \dots$ (19)

The capacitance C may be found by calculating the work done in moving a unit charge from M to L against the charge on wire A. This is

$$\frac{2Q}{\pi}\int_0^{2\pi}\left[1/2 + L_1\cos\theta + \dots + L_n \cos n\theta + \dots\right]\left[\text{logh}\left(\frac{s-a}{a}\right) + \cos\theta + \frac{1}{2}\cos 2\theta + \dots + \frac{1}{n}\cos n\theta + \dots - \frac{a}{s-a}\cos\theta - \frac{a^2}{2(s-a)^2}\cos 2\theta - \dots - \frac{a^n}{n(s-a)^n}\cos n\theta - \dots\right] d\theta$$

This is equal to $\dfrac{Q}{2C}$. Therefore,

$$1/C = 4\left[\text{logh}\,\frac{s-a}{a} + L_1\left\{1 - \frac{a}{s-a}\right\} + \dots + L_n/n\left\{1 - \frac{a^n}{(s-a)^n}\right\} + \dots\right] \tag{20}$$

An alternative expression of different algebraical form can be obtained by finding the work done against the charges on both wires by carrying a unit charge to the surface of one wire from the neutral point midway between the two wires. This gives

$$1/C = 4\left[\text{logh}\, s/a - \frac{a}{s} L_1 - \frac{a^2}{2s^2} L_2 - \dots - \frac{a^n}{n s^n} L_n - \dots\right] \tag{21}$$

Formulas (**20**) and (**21**) both give exactly the same numerical results as the standard formula:

$$1/C = 4\,\text{logh}\,\frac{s + \sqrt{s^2 - 4a^2}}{2a} = 4\cosh^{-1}\frac{s}{2a}\ * \tag{22}$$

Example of Single-Phase Overhead Line

Let $\qquad s/a = 10$

Then $1/C = 9.16972$ by formulas (**20**), (**21**) and (**22**), in absolute units.

Two-Conductor Sheathed Cable (Capacitance of the Sheath against the Two Conductors)

Let the radius of the conductors of the cable be a cm. and let the inside radius of the sheath be c cm. Then, as is well known in connection with calculations of capacitance, image conductors can be assumed at a distance s and of radius a', which will carry charges equal and opposite to those of the cable conductors. The inner surface of the sheath can be considered as a surface of zero potential, carrying no charges. The dimensions a' and s are given by

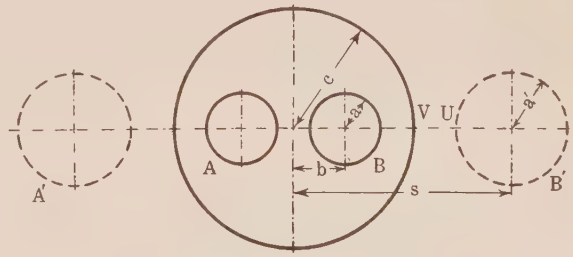

Fig. 3—Two-Conductor Sheathed Cable

$$a' = \frac{a\,c^2}{b^2 - a^2} \tag{23}$$

and

$$s = \frac{b\,c^2}{b^2 - a^2}\ ** \tag{24}$$

The first additional density of charge at any point of the surface of conductor B, due to uniformly distributed charges on the other three conductors may be calculated in a manner similar to that used for an overhead single-phase circuit. The angle θ is used for the conductor to the right of B and the angle $(\theta - \pi)$ is used for the conductors to the left. The first additional density on B is

$$\frac{Q}{\pi a}\sum_{n=1}^{n=\infty} A_n \cos n\theta \tag{25}$$

*For the derivation of formula (**22**) see "Transmission Line Formulas" by H. B. Dwight, 1st edition, Chapter XIII, or other books on alternating-current theory.

**"Elements of the Mathematical Theory of Electricity and Magnetism," by J. J. Thomson, fourth edition, pages 149 and 176.

$$\text{where } A_n = \left(\frac{a}{s-b}\right)^n - \left(\frac{-a}{2b}\right)^n + \left(\frac{-a}{s+b}\right)^n \tag{26}$$

The first additional density on B' is

$$\frac{Q}{\pi a'} \sum_{n=1}^{n=\infty} F_n \cos n\gamma \tag{27}$$

$$\text{where } F_n = -\left(\frac{a'}{s-b}\right)^n + \left(\frac{a'}{2s}\right)^n - \left(\frac{a'}{s+b}\right)^n \tag{28}$$

The second additional density on B is

$$\frac{Q}{\pi a} \sum_{n=1}^{n=\infty} B_n \cos n\theta \tag{29}$$

where $B_n =$

$$-\left(\frac{a}{s-b}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{a'}{s-b}\right)^k F_k$$
$$-\left(\frac{-a}{2b}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{-a}{2b}\right)^k A_k$$
$$-\left(\frac{-a}{s+b}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{a'}{s+b}\right)^k F_k \tag{30}$$

The second additional density on B' is

$$\frac{Q}{\pi a'} \sum_{n=1}^{n=\infty} G_n \cos n\gamma \tag{31}$$

where $G_n =$

$$-\left(\frac{a'}{s-b}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{a}{s-b}\right)^k A_k$$
$$-\left(\frac{a'}{2s}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{a'}{2s}\right)^k F_k$$
$$-\left(\frac{a'}{s+b}\right)^n \sum_{k=1}^{k=\infty} \frac{(n+k-1)!}{(n-1)!\,k!} \left(\frac{-a}{s+b}\right)^k A_k \tag{32}$$

For C_n and H_n use the same formulas as for B_n and G_n except change A to B and F to G. Then for D_n and I_n change B to C and G to H, and so on.

The total density on B is

$$\frac{Q}{\pi a} \left[1/2 + \sum_{n=1}^{n=\infty} L_n \cos n\theta\right] \tag{33}$$

$$\text{where} \quad L_n = A_n + B_n + C_n + \ldots \tag{34}$$

The total density on B' is

$$\frac{Q}{\pi a'} \left[-1/2 + \sum_{n=1}^{n=\infty} M_n \cos n\gamma\right] \tag{35}$$

$$\text{where} \quad M_n = F_n + G_n + H_n + \ldots \tag{36}$$

It is now necessary to calculate the work done against all the charges, when carrying a unit charge from the surface of an image conductor to the surface of one of the conductors of the cable. This quantity of work is twice the potential between the grounded sheath and the two conductors which are taken connected in parallel in this calculation. Therefore,

$$\text{Work} = \frac{4Q}{C}$$

where C is the capacitance of the sheath on one side and the two conductors on the other. The amount of the work is calculated by using equation (1) of this paper, and the following result is obtained:

$$1/C = \operatorname{logh} \frac{(s-b-a')(s-b-a)(s+b-a')(s+b+a)}{a\,a'(2b+a)(2s-a')}$$
$$+ \sum_{n=1}^{n=\infty} L_n/n \left[1 - \left(\frac{a}{s-b-a'}\right)^n - \left(\frac{-a}{s+b-a'}\right)^n + \left(\frac{-a}{2b+a}\right)^n\right] - \sum_{n=1}^{n=\infty} M_n/n \Bigg[1$$
$$- \left(\frac{a'}{s-b-a}\right)^n - \left(\frac{a'}{s+b+a}\right)^n + \left(\frac{a'}{2s-a'}\right)^n\Bigg] \tag{37}$$

Equation (37), in connection with (23), (24), (26), (28), (30), (32), (34) and (36), is used in calculating numerical values of capacitance.

Example, Two-Conductor Cable. $a = 1, b = 2, c = 5$ Then $s = 50/3$ and $a' = 25/3$.

This corresponds to $t/T = 1$ and $\dfrac{T+t}{d} = 1$ in Mr. Simons' paper previously referred to, Table I, and the calculation gives a geometric factor of 1.730 to compare with 1.718 given by the graphical method. The difference in this case is less than one per cent.

The geometric factor suggested by D. M. Simons, for capacitance of an n-conductor cable, between the sheath on one side and the n conductors on the other, is

$$G_1 = \frac{k\,n}{2\,C}$$

where k is the permittivity of the dielectric, and C is the capacitance per unit length for the above connection. The geometric factor can also be used in formulas for thermal resistance.

Three-Conductor Sheathed Cable, (Capacitance of the Sheath Against the Three Conductors)

The size and location of the image conductors are given by the following equations which are similar to (23) and (24) of the calculation for a two-conductor cable:

$$a' = \frac{c^2\,a}{b^2 - a^2} \tag{38}$$

$$s + b = \frac{c^2\,b}{b^2 - a^2} \tag{39}$$

The first additional density on A, due to uniform density of charge on all the other conductors is

$$\frac{Q}{\pi a} \sum_{n=1}^{n=\infty} A_n \cos n\,\theta \tag{40}$$

where

$$A_n = \frac{a^n}{s^n} - \frac{2\,a^n}{t^n} \cos n\,\delta + \frac{2\,a^n}{u^n} \cos n\,\sigma \tag{41}$$

where Q is the electric charge per centimeter on each conductor, and where the various dimensions and angles are indicated in Fig. 4.

The first additional density on A' is

$$\frac{Q}{\pi a'} \sum_{n=1}^{n=\infty} F_n \cos n\,\gamma \tag{42}$$

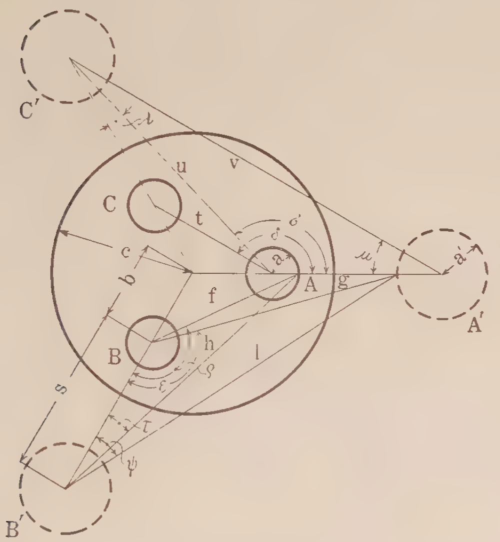

FIG. 4—THREE CONDUCTOR SHEATHED CABLE

where

$$F_n = -\frac{a'^n}{s^n} - \frac{2\,a'^n}{u^n} \cos n\,\lambda + \frac{2\,a'^n}{v^n} \cos n\,\mu \tag{43}$$

The second additional density on A is

$$\frac{Q}{\pi \cdot a} \sum_{n=1}^{n=\infty} B_n \cos n\,\theta \tag{44}$$

$$\text{where } B_n = -\,a^n/s^n \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a'^k}{s^k} F_k$$

$$-\frac{2\,a^n}{t^n} \cos n\,\delta \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a^k}{t^k} A_k \cos k\,\delta$$

$$-\frac{2\,a^n}{u^n} \cos n\,\sigma \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a'^k}{u^k} F_k \cos k\,\lambda \tag{45}$$

The second additional density on A' is

$$\frac{Q}{\pi a'} \sum_{n=1}^{n=\infty} G_n \cos n\,\gamma \tag{46}$$

$$\text{where } G_n = -\,a'^n/s^n \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a^k}{s^k} A_k$$

$$-\frac{2\,a'^n}{u^n} \cos n\,\lambda \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a^k}{u^k} A_k \cos k\,\sigma$$

$$-\frac{2\,a'^n}{v^n} \cos n\,\mu \sum_{k=1}^{k=\infty} \frac{|\underline{n+k-1}}{|\underline{n-1}\;|\underline{k}}\;\frac{a'^k}{v^k} F_k \cos k\,\mu \tag{47}$$

For C_n and H_n use the same formulas as for B_n and G_n except change A to B and F to G. Then for D_n and I_n change B to C and G to H, and so on.

The total density on A is

$$\frac{Q}{\pi a} \left[1/2 + \sum_{n=1}^{n=\infty} L_n \cos n\,\theta\right] \tag{48}$$

where

$$L_n = A_n + B_n + C_n + \ldots \tag{49}$$

The total density on A' is

$$\frac{Q}{\pi a'} \left[-\,1/2 + \sum_{n=1}^{n=\infty} M_n \cos n\,\gamma\right] \tag{50}$$

where

$$M_n = F_n + G_n + H_n + \ldots \tag{51}$$

The work done in carrying a unit charge from the surface of conductor A' to the surface of conductor A, along the line joining their centers, is equal to

$$\frac{6\,Q}{C}$$

where C is the capacitance of the condenser consisting of the sheath on one side and the three conductors on the other.

The result of integrating the work, due to all the charges is

$$1/C = 1/3 \operatorname{logh} \frac{(s-a')\,(s-a)}{a\,a'} + 2/3 \operatorname{logh} \frac{g\,h}{f\,l}$$

$$+\,1/3 \sum_{n=1}^{n=\infty} L_n/n \left[1 - \left(\frac{a}{s-a'}\right)^n + 2\,(a/f)^n \cos n\,\rho - 2\,(a/g)^n \cos n\,\epsilon\right]$$

$$-\,1/3 \sum_{n=1}^{n=\infty} M_n/n \left[1 - \left(\frac{a'}{s-a}\right)^n - 2\,(a'/h)^n \cos n\,\tau + 2\,(a'/l)^n \cos n\,\psi\right] \tag{52}$$

EXAMPLE, THREE-CONDUCTOR CABLE

$$a = 1, \quad b = \sqrt{3}, \quad c = 2 + \sqrt{3}$$

This corresponds to $t/T = 1$ and $\dfrac{T+t}{d} = 1/2$ in Mr. Simons' paper previously referred to, Table I. The calculation gives a geometric factor of 1.465 to compare with 1.455 obtained by the graphical method. The difference is less than one per cent.

A SIMPLIFIED SLIDE RULE METHOD FOR CALCULATING TRANSFORMER EFFICIENCIES

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In transformer design, about the last thing to be determined is the efficiency, and, as all the principal constants have been worked out, it is rather a bother. When it comes to distribution or listed transformers, the work of calculating the different efficiencies is particularly onerous on account of the very number of them.

I once was called upon to work out some 1200 efficiencies, and developed a method which will be outlined below. Without detracting from the excellence of divers charts and graphical methods, I would point out that mental inertia afflicts the majority of us, and while knowing some helpful chart exists, this inertia often prevents an engineer from acquiring it. Moreover, he may be often out in the field, or in discussion with some client, and not have access to a chart at the time.

But on the other hand, every engineer has his slide rule with him (or can borrow one) no matter where he is called on business, and under these conditions a simple and ready slide rule method is a help.

While I do not claim originality for the method, and others may well have developed the same, the fact is, that in many years of design abroad, I have had occasion to show it to several fellow designers, all of whom appreciated its agreeable simplicity and to none of whom it was familiar in all its details. This encourages me to think that a more general dissemination of the method would not be without value.

Efficiency in general is defined as:

$$E = \frac{100\,P}{P + L} \tag{1}$$

Where E = efficiency in per cent.
P = output, power or capacity.
L = total losses at power P.

As transformer efficiencies vary from about 90 to 99 per cent, this does not lend itself to accurate determination by a direct setting of the slide rule, and equation (1) can be conveniently transformed into

$$E = \frac{100\,P}{P + L} = \frac{100\,P + 100\,L - 100\,L}{P + L}$$

$$= \frac{100\,(P + L)}{P + L} - \frac{100\,L}{P + L}$$

$$E = 100 - \frac{100\,L}{P + L} \tag{2}$$

Now as in transformers, the losses are small in proportion to the capacity, the fraction in expression (2) falls on the left, or more accurately divided part of the slide rule, and having deduced this fraction it is subtracted from 100 either mentally like a cologarithm, or on a slip of paper, and results in an accuracy of 1/100 of one per cent.

As every engineer knows, transformer losses are composed of two parts

(a) the iron loss Call this I
(b) the copper loss Call this C

The iron loss, I, is independent of the load, while the copper loss varies as the square of the current or load.

Hence as specially applied to transformers the equation for efficiency will be

$$E = 100 - \frac{100\,(I + C)}{P + I + C} \tag{3}$$

For the purpose of comparison and demonstration I will now run through the calculations by the ordinary French method, and subsequently, the same efficiencies by the simplified method.

Suppose we desire the efficiencies of the following transformer

833 kv-a. 60-cycle single-phase 12,000-volt 230-volt with 4150 watts core loss and 12,600 full load copper loss, at 1¼ load

Full load and at 100 per cent, 80 per cent and 60 per cent power factor
¾ load
½ load
¼ load

For convenience we will use the French method of designating the load, namely,

1¼ load = 5/4 load
Full load = 4/4 load
¾ load = ¾ load
½ load = 2/4 load
¼ load = ¼ load

the reason for which will be apparent later.

The calculation will appear as follows:

100 Per Cent Power Factor

Load	5/4	4/4	3/4	2/4	1/4
Iron loss I	4,150	4,150	4,150	4,150	4,150
Copper loss C	19,700	12,600	7,090	3 150	788
Total $L = I + C$	23 850	16 750	11,240	7,300	4,938
P	1,040,000	833,000	625,000	416,000	208,000
$P + I + C$	1,063,850	849,750	636,240	423,300	212,938
$\frac{100\,(I + C)}{P + I + C}$	2.24	1.97	1.77	1.72	2.31
E	97.76	98.03	98.23	98.28	97.69

80 Per Cent Power Factor

$I + C$	23,850	16,750	11,240	7,300	4,938
P	833,000	667,000	500,000	333,000	167,000
$P + I + C$	856,850	683,750	511,240	340,300	171,938

80 Per Cent Power Factor

	5/4	4/4	3/4	2/4	1/4
$\frac{100\,(1+C)}{P+1+C}$	2.78	2.45	2.2	2.14	2.87
E = ...	97.22	97.55	97.8	97.86	97.13

60 Per Cent Power Factor

$I + C$..........	23,850	16,750	11,240	7,300	4,938
P..............	625,000	500,000	375,000	250,000	125,000
$P + I + C$.....	648,850	516,750	386,240	257,300	129,938
$\frac{100\,(I+C)}{P+1+C}$	3.67	3.23	2.91	2.84	3.79
E = ...	96.33	96.77	97.09	97.16	96.21

There are rather a lot of figures.

However, as we are after a result in per cent, we are at liberty to reduce everything to a percentage basis before starting to calculate, so by the new method the calculation will stand as follows:

Full load capacity P = 100 per cent = 833 kv-a.
Iron loss I = 0.498 per cent = 4,150 watts
Copper loss C = 1.51 per cent = 12,600 watts

As the copper loss varies as the square of the load it will be:

Load	loss
5/4	$(5/4)^2$ = 25/16 × full load loss
4/4	$(4/4)^2$ = 16/16 " " " "
3/4	$(3/4)^2$ = 9/16 " " " "
2/4	$(2/4)^2$ = 4/16 " " " "
1/4	$(1/4)^2$ = 1/16 " " " "

Therefore to determine the respective copper losses it is sufficient to place the figure 16 under the per cent full load and read off the results immediately opposite 25, 16, 9, 4 and 1.

Doing this we have

100 Per Cent Power Factor

Load...........	5/4	4/4	3/4	2/4	1/4
I Per cent......	0.498	0.498	0.498	0.498	0.498
C Per cent......	2.36	1.15	0.85	0.378	0.0945
$(C + I)$ Per cent	2.858	2.008	1.348	0.876	0.5925
P Per cent......	125.	100.	75.	50.	25.
	127.858	102.008	76.348	58.76	25.5925
$\frac{100\,(I+C)}{P+I+C}$...	2.24	1.96	1.77	1.73	2.32
E = ...	97.76	98.04	98.23	98.27	97.68

80 Per Cent Power Factor

$(I + C)$ Per cent	2.858	2.008	1.348	0.876	0.5925
P Per cent......	100.	80.	60.	40.	20.
$(P + I + C)$ Per Cent.........	102.858	82.008	61.348	40.876	20.5925
$\frac{100\,(I+C)}{P+I+C}$...	2.78	2.44	2.2	2.15	2.88
E = ...	97.22	97.56	97.8	97.85	97.12

60 Per Cent Power Factor

	5/4	4/4	3/4	2/4	1/4
$(I + C)$ Per cent	2.858	2.008	1.348	0.876	0.5925
P..............	75.	60.	45.	30.	15.
$(P + I + C)$....	77.858	62.008	46.348	30.876	15.5925
$\frac{100\,(I\ C)}{P+I+C}$...	3.67	3.23	2.92	2.85	3.8
E = ...	96.33	96.77	97.08	97.15	96.2

This agrees with the above figures to slide rule accuracy and the divergence is not more than 1/100 of 1 per cent.

We have already eliminated a good many figures, but in practise many of the operations may be performed mentally. Moreover it is usual to give efficiencies at unity and 80 per cent power factor only, so that the final calculation will stand as follows:—

100 Per Cent Power Factor

Load...........	5/4	4/4	3/4	2/4	1/4
I Per cent.......	0.498	0.498	0.498	0.498	0.498
C Per cent......	2.36	1.51	0.85	0.378	0.0945
$(I + C)$ Per cent	2.858	2.008	1.348	0.876	0.5925
$\frac{100\,(I+C)}{P+I+C}$...	2.24	1.96	1.77	1.73	2.32
E..............	97.76	98.04	98.25	98.27	97.68

80 Per Cent Power Factor

$\frac{100\,(I+C)}{P+I+C}$...	2.78	2.44	2.2	2.15	2.88
E..............	97.22	97.56	97.8	97.85	97.12

Thus we have very few figures to set down and all of them of a convenient magnitude. The method to be followed is this:

Remember that the power corresponds to the figures:

at 100 per cent power factor	125	100	75	50	25
at 80 per cent power factor	100	80	60	40	20

Set the slider over the loss in question say at 5/4 and divide by 125 + 2.858 = 127.9 making the addition mentally. Leave the slider in place and divide by 100 + 2.858 = 102.9 mentally. This gives the figures 2.24 and 2.78 rapidly. Pass to 4/4, divide first by 100 + loss, and second 80 + loss, and similarly with each of the others.

The method can also be worked backward. Suppose in the above transformer we have one efficiency given and one of the losses. What is the other loss?

Given 833 kv-a. = 100 per cent P
Efficiency 4/4 100 per cent power factor 98.04
Core loss 4150 W = 0.498 per cent
What is the copper loss?

Method:

Subtract 98.04 from 100 = 1.96

Place left end of slide rule on 1.96 and move slider till reading on upper scale plus 100 is the same as lower scale. This will occur at 2. That is, 2 divided by 102 = 1.96. The total loss is therefore 2 per cent.

Total loss = 2
Iron loss 0.498

Copper loss 1.502 = 12,500 watts.

The true figure is 12,600.

Another example:

Given two efficiencies what are the two losses?

Given

833 kv-a. = 100 per cent
Efficiency 4/4 100 power factor 98.04
Efficiency 2/4 100 power factor 98.27
Deduct each of these from 100.
100 − 98.04 = 1.96
100 − 98.27 = 1.73
Find the fraction as above.

$$1.96 = \frac{2}{102} (\times 100)$$

$$1.73 = \frac{0.88}{50.8} (\times 100)$$

The respective losses are 2 per cent and 0.88 per cent.

Now at full load Loss $= C + I$

and at 2/4 Loss $= \frac{C}{4} + I$

We have 2 equations

$$+ I = 2.$$

$$\frac{C}{4} + I = .88$$

Eliminate I $\frac{3\,C}{4} = 1.12$ whence $C = 1.495 = 12{,}450$
$I = 0.505 = 4{,}200$

for the true figures 12,600 and 4150.

Similarly, the respective losses may be determined from any other pair of efficiencies.

The beauty of this method lies in its independence of the actual power, and is always the same whatever the transformer. Its very sameness gives rapid practise and one soon becomes very expert. The figures are of convenient magnitude, and comparisons between transformers are easy. This tends to eliminate errors. The engineer would indeed have to know where his decimal point was, to work the ordinary method backward.

And as an example of rapidity I once worked out 180 efficiencies (ten to a transformer) in 50 minutes, an average of 17 seconds each.

Electrical Applications to Irrigation Pumping

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IRRIGATION, or what is known as artificial watering of the soil, has been practised in the agricultural districts of our country, and in parts of European and Oriental countries for a great many years.

Probably the first irrigation of any importance on our continent was carried on by the Mormons of Utah. Irrigation at that time naturally did not involve the many considerations that enter into its practise now, primarily, because the area to be watered was very limited, and there was an abundance of water available from the natural flow of the mountain streams to take care of the crops in this limited area.

By reason of the large areas under cultivation at the present time and the natural increase in the use of water for domestic and industrial purposes, the conditions today have changed and we no longer find the open ditch along each side of the streets of the cities and villages of Utah filled to the brim with the sparkling water that twenty-five years ago greeted our vision as we passed through this territory.

The geological structure of that territory and its natural slope of the drainage area to the Colorado River has made artesian water available for irrigation to a large extent throughout the sections of Utah where agricultural development has been most marked in the past, and the pumping of the sub-soil waters to the surface for irrigation as practised in Southern and Central California for so many years is only just beginning to appear on a large scale in the semi-arid sections of that state.

By reason of its geographical location and relatively small population, the agricultural development of Utah is not likely to be as rapid as in California, so their water problem is not as serious as ours, but those who were fortunate enough to see the beautiful streams of water that at one time raced along the streets of their cities and towns many years ago, and who have viewed the same territory within the past few years, will fully realize the importance of conserving the flow of our California streams and curb the wasteful methods of applying this water to our lands.

As the Utah people were pioneers in adopting irrigation, it is only natural that the agricultural college in that state should be among the first to make a scientific study of the subject, and through the channels of the agricultural colleges throughout the west, the reclamation service and our own University of California much reliable information on the subject has been made available. Unfortunately, due to our present day mad race for supremacy, the average tiller of the soil has paid very little attention until recently to the valuable information placed within his reach, but rather each farmer had his own particular ideas regarding the kind of crop he raised and the methods

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of irrigating it. The lack of cooperation between the different water users and the wasteful methods of applying water to their crops are gradually leading to a condition that must sooner or later receive the careful consideration of every man interested in the successful development of our great state.

That excessive waste occurs by reason of the lack of proper flood control is common knowledge. Our flood waters instead of being slowly communicated to the sea through large drainage areas, as is the case in many sections of the country, rush over the surface of the earth for a few miles to the sea and with the exception of a small quantity that may enter the coarse alluvial formations which usually reach the surface only near the foot of the mountains, very little ever reaches the reservoirs underlying the surface of our valleys.

The problem may be, and no doubt will be remedied by storing the flood waters in the mountains, and controlling the flow of the streams below to a degree that will allow spreading the stored water over areas of such geological structure that it will be communicated to our great underground reservoirs and be made available for the use of our crops.

The matter of waste in the application of water for irrigation is purely a problem of educating the user, and as the proper selection of crops and the proper application of the available water to these crops will sooner or later mean success or failure, it is reasonable to suppose that the work of such institutions as the agricultural experiment stations and farm bureaus throughout the State will correct this condition to a great extent.

It is not reasonable to suppose that throughout a territory where the average seasonal rainfall is not more than ten inches, you will be able to put 12 ft. of water on the land for any number of years without depleting the supply and yet I have personally tested many pumping plant installations where this has been done. The low cost of power for agricultural purposes in this state as compared with other portions of the United States, has no doubt been a factor in promoting the waste.

We have all of the natural advantages of climate to produce ideal crops and with the cheap power, the conservation of our water supply and the elimination of waste in application, California should become one of the greatest agricultural states in the Union.

We have only enough rainfall to properly mature a crop when all of our territory is developed, and the waste methods of open ditch irrigation must be abandoned before many years, and be replaced by storage of the rainfall in our underground reservoirs, and the still further adoption of irrigation pumping.

When we consider irrigation pumping, we must readily realize that due to the high state of development of the modern electric motor and its adaptability to the various forms of pumping equipment, the lack of personal attention required, the low cost of electric energy for agricultural purposes, the farmer can ill afford to spend his time manufacturing power by other means rather than purchasing the finished product in the form of electric power and devoting his time to the study of the problem that is really his—the production of the greatest amount from a given area.

The agricultural lands of California are located at the foot of mountains throughout which hundreds of millions of dollars have been and are being spent for the development of hydroelectric power; the territory to be developed is covered by a network of transmission and distribution lines, the equal of which is not to be found in any similar agricultural area in the world, and which bring the energy stored up in the snow drifts of the high Sierras to the very door of the prospective consumer. In the face of these conditions it is to be expected that when we think of irrigation pumping, we should think of electric power and the modern inexpensive reliable and efficient electric motor with its control equipment, as a means of driving our pumping machinery.

The low first cost of the electric motor, its low rate of depreciation, and the extreme flexibility of application to the problems of irrigation pumping make it far superior to any other form of drive.

In laying out an irrigating system that is to expand gradually over a term of years, the consumer can begin with the small investment necessary to install his first unit and add others of larger or smaller size as the system expands until finally the plant is complete, an extremely flexible and efficient installation, any part of which can be used singly or grouped with other units to meet the varying demands for water, and at all times operate efficiently. By reason of the excessive fixed charges on other forms of drive, such an arrangement is impractical, particularly when you consider the fact that the irrigation load is seasonal and the yearly load factor seldom exceeds 20 per cent.

In the early stages of irrigation pumping in Southern California, vertical centrifugal pumps installed on wood frames in shallow pits were used in the majority of cases but the rapid development of the large areas of irrigated lands caused a gradual lowering of the pumping levels, and the development of what is known as the deep well turbine designed to lower into the well casing beyond the bottom of the pits, entirely changed the practises formerly in vogue until today; the well casings varying in size from 10 in. to 24 in. in diameter are started from the surface of the ground and a deep well turbine is lowered into the well until the impellers are below the pumping water levels, thus making it unnecessary to prime the unit in order to start. The pump head proper is set on a foundation built around the well casing at the surface and entirely covers the well, thus preventing anything from entering the casing.

As well turbines are required to be of small diameter in order that they may be easily lowered into the well casings and as their runners are often set as deep as

300 ft. below the surface, they are essentially high speed machines and particularly suited to electric drive. Such pumps are often designed with non-overloading impellers having a fairly constant horse-power line in order to prevent excessive overloads when variations in the pumping levels occur, and are then direct-connected to a vertical shaft motor. When you stop to consider that such an installation of 200-h. p. capacity with all of its control equipment can be installed in a space not to exceed 10 ft. square, you can readily see what a saving in first cost results from the application of electric drive. Such an installation eliminates belts with their consequent power losses and necessary building space to obtain the proper driving centers and prolongs the life of the pumping machinery.

The application of electric drive to pumping equipment in California has played no small part in the development of the deep well turbine which ten years ago was a very inefficient and troublesome type of unit and which today has become one of the most efficient and satisfactory installations obtainable. This results from the fact that in the application of electric drive, as in no other form of drive, the consumer is afforded a means of easily checking the input to the motor by timing the speed of the meter disk and a very keen rivalry has existed among the manufacturers of well turbines in building a piece of apparatus that will show the highest efficiency. In this connection, the Southern California Edison Company employs a force of engineers with all equipment necessary to make pumping plant tests to determine the efficiency and other operating conditions existing at such plants and to make recommendations for improving the efficiency. No charge is made for this work as it is considered to be a part of the service to consumers in the agricultural districts covered by this system.

Well turbines are used in California generally where it is necessary to deliver streams of one sec-foot or more from small diameter wells, while in sections where smaller streams are to be pumped from depths of several hundred feet, the piston type of pump is often used, and in such an installation a slow-speed motor designed for high starting torque and connected through a chain or short belt and idler drive eliminates much building space and makes an ideal form of installation.

So far I have been speaking only of the motor alone and its application to pumping machinery, but no less important is the feature of its control. A consumer who wishes to add a reasonable amount for refinements in control can obtain equipment that will start and stop his plant automatically through float switches operated by changing water levels through time clocks, through push buttons installed for remote manual control, and many other features that make it possible for him to devote his entire time and the time of his assistants to the production of his crops.

In the early stages of pumping plant testing by public utility corporations in California, some very interesting results were obtained from the fact that the tests covered all kinds of pumps installed without regard to their fitness for the service they were expected to render.

Experience such as this seldom falls to the lot of the average consulting engineer as he usually is employed to lay out a plant along recognized engineering lines or to give advice to some consumer who has previously employed the services of a consulting engineer and therefore has a plant that is at least to some extent fitted to his conditions, while a utility testing pumping plants as a part of its service to consumers tests many installations that, like Topsy, "just grew up."

Some interesting facts covering approximately 300 tests of pumping plants made prior to 1917 are as follows:

Average lift was 92 ft.
" stream was 828 gal. per min.
" pump efficiency 51 per cent
" overall efficiency 42.4 per cent
Ratio overall to pump 0.83
Kw-hr. per acre foot lifted one foot 2.42.

These tests included pumps of all types, delivering streams from 150 to 2700 gal. per min. against heads varying from 30 to 600 ft. and are therefore of no value when applied to an individual case.

The greater portion of these tests was made on 4, 5, 6 and 7-in. centrifugal pumps mostly of vertical-shaft types and the variation from the mean efficiency for different heads was as follows:

Less than 50 ft.	− 4.9
50 to 75 ft.	− 0.3
75 to 100 ft.	+ 4.7
Over 100 ft.	+ 4.7

Since the time these tests were made, pumps of the centrifugal types have been very much improved and more attention has been given to fitting them to the conditions under which they are to operate, with the result that much higher efficiencies are being obtained.

Generally speaking, pumps in the irrigation districts may be divided into the following classes:

1. Those installed in shallow pits where the water levels are within a few feet of the bottom of the pit and where water is delivered at the surface.
2. Those installed under similar conditions but delivering water into a pipe line with outlets at widely varying levels.
3. Those installed in deep wells with the well casings beginning at the surface of the ground, and where water may be delivered at the surface or into pipe line with varying heads.
4. Those pumping from a reservoir or tank on the surface to a similar reservoir or tank at a higher level.

Plants in group No. 1 are simple installations usually consisting of a single-stage horizontal centrifugal pump direct-connected to a three-phase motor. In-

stallations of this kind are found throughout central California and are usually from three- to ten-h. p. capacity. The streams delivered by these plants seldom exceed 300 gal. per min. and the lift is usually less than 50 ft.

Naturally, a unit of this type, pumping against a low head, seldom shows more than 40 per cent overall efficiency, but as the lift is very low, the input per unit of water delivered to the land is extremely small. Plants of this type usually operate continuously during an irrigation season of five months each year and as the variation in head is very small it is only necessary to see that the unit is provided with a standard impeller of the proper diameter to deliver its economical capacity at the head involved.

Units in group No. 2 constitute rather a different problem, inasmuch as water is to be delivered against various heads through a single pipe line.

The selection of equipment for such a condition depends largely on the acreage to be irrigated from each outlet.

From the standpoint of pump efficiency the triplex plunger pump is well adapted to such a condition as the action of the plungers maintains a constant stream of water, the input varying directly with the lift. Such units are seldom used, however, as the cost per unit of capacity is much higher than with the centrifugal pumps, and as the monthly load factor during the five to seven months of the irrigation season in sections of Southern California where such plants are found seldom exceeds 20 per cent, the first cost of installations larger than 450 gal. per min. is seldom justified. When the hours of operation are sufficiently long to justify the first cost of a triplex pump, the input will seldom exceed 1.5 kw-hr. per acre foot lifted one foot.

When centrifugal pumps are used to meet such a condition, one of three plans may be employed, *viz.*, a belted pump operated at different speeds by changing motor pulleys for each change of head; two pumps direct-connected through sliding couplings to a single motor, one to operate singly against the lowest head, one to operate singly against an intermediate head and the two in series against a third head; or a single unit designed for a flat horse-power line and speeded to deliver its most economical capacity at the head supplying the greatest area. This latter plan is often adopted with excellent results.

Characteristic curves of such a unit are shown in Fig. 1.

It will be seen that this unit delivers a stream varying from 1000 to 1500 gal. per min. against a head of from 270 to 340 ft., the output of the motor varying from 145 to 155 h. p. and maintaining an efficiency varying only about three per cent over the entire range of head and capacity.

Under group No. 3 we find the deep well double-acting piston type pump, the multi-stage centrifugal well turbine and the multi-stage marine or propeller-type turbine. The selection of types in this case is governed by the size of the well casing and the stream required.

Assuming the well to be 14 in. in diameter and the lift to be about 120 feet, the piston type of pump would be limited to a capacity of approximately 450 gal. per min., while the centrifugal turbine would have an economical range of from 450 to 1200 gal. per min.

As this unit will have to deliver water against varying heads, it is desirable to design it with a flat horse-power line. The performance curves shown in Fig.

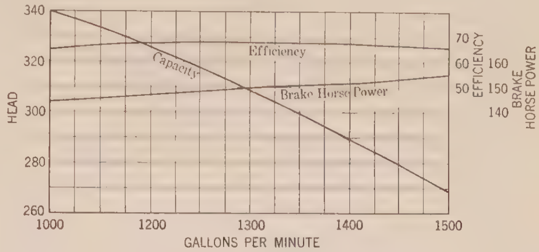

Fig. 1—6 by 18-In. Two-Stage Series Pump, Rev. per Min. 1450

2 cover such a unit. It will be noted that this is a three-stage unit delivering water over a range of head from 78 to 115 ft. with a range of delivery from 750 to 1200 gal. per min. with practically no variation in input and only five per cent variation in efficiency.

Such a unit is very desirable in cases where there is a wide seasonal range of pumping levels as often occurs in sections of Southern California.

The marine or propeller-type turbine will deliver a much larger stream of water from a given diameter

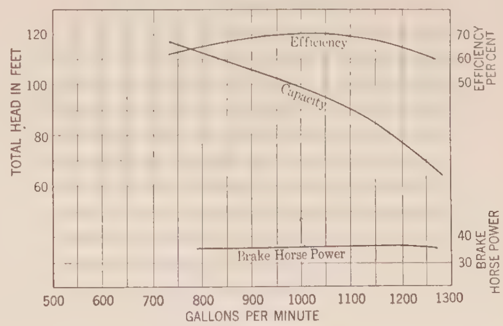

Fig. 2—Three-Stage Deep Well Pump, Rev. per Min. 1450

casing than any of the other types, but the input increases as the head increases which is exactly the reverse of the standard centrifugal pump characteristic.

Fig. 3 shows characteristic curves of a 10-stage unit of this type capable of entering a 10-in. well casing.

These curves cover direct connection to a 6-pole motor operating on either 50- or 60-cycle systems.

Under conditions mentioned for Group No. 4, the units operate at practically a constant head and can therefore be designed to show the highest possible efficiency at that particular head without regard to the shape of the curves at other points. This condition can be efficiently handled by slow moving plunger types of pumping machinery or by centrifugal pumps. The former types will show somewhat higher efficiencies

than the latter but the selection of types is governed by the load factor of the plant and the relative cost of installation.

The fact that the yearly load factor of the greater portion of such plants is very low seems to lend itself particularly to the latter types. Fig. 4 shows an actual field test on two such units on the system of the Southern California Edison Company.

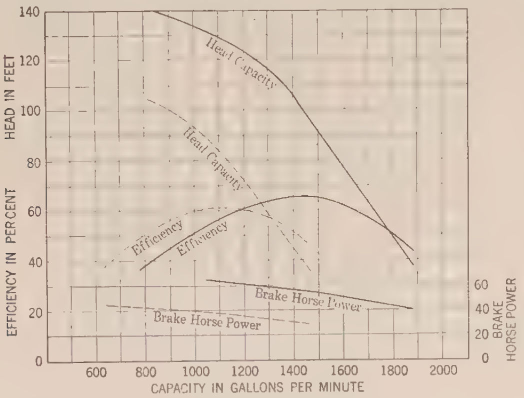

Fig. 3—Marine Turbine Pump, 10-Stage, Speeds 1140 Rev. per Min., 960 Rev. per Min.

These were 8-in. two-stage horizontal centrifugal pumps direct-connected to 175-h. p. motors with their curves almost identical; however pump 1 was taking its suction from a small receiving basin into which a stream of water was running and as the water lowered in the basin it took in a charge of air and dropped off several points in efficiency.

As the normal operating head at this plant was 325 ft., it can be seen that the difference in efficiency between

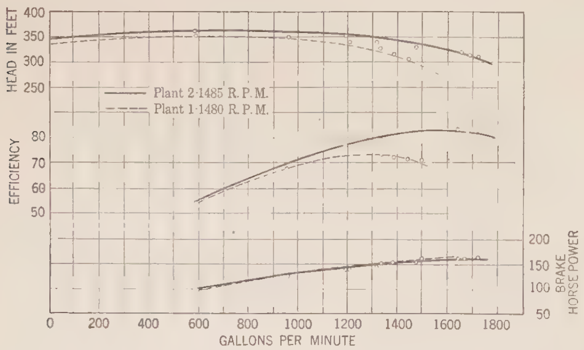

Fig. 4—Eight-In. Two-Stage Direct-Connected Horizontal Centrifugal Pumps
Plant 2—1485 Rev. per Min.
Plant 1—1480 " " "

the result shown and the possible efficiency of any other type of unit would not justify any material investment, particularly under a low yearly load factor.

The Southern California Edison Company maintains a department for testing pumping plants for its consumers as a part of its regular service. These tests include, standing water levels, pumping water levels, total lift, water delivered, kw. input to motor, overall efficiency, pump efficiency, kw-hr. per miner's inch 24 hours, kw-hr. per acre foot of water, and per cent of full-load input to motor.

When tests are worked up, a complete report is made to the consumer with recommendation that will improve his efficiency or lower his unit cost of delivering water to his lands.

A record of the test with description of the equipment, if filed in the office for future reference or comparison with subsequent checks that are often made after changes in equipment, is made from time to time.

The test card used for collecting the data and filing for reference is shown as Fig. 5.

The scope of the irrigation subject in California is so broad that it cannot well be covered in a single article and while the general conditions have been somewhat covered in this paper, it is thought that more detailed information can be brought out during a discussion of the points most interesting to the members attending the convention.

Generally, the irrigation load is carried on 11,000-volt distribution lines running through the rural districts. The motors are usually 220- or 440-volt,

PUMPING PLANT TEST

Plant ...... District ...... Date ......
ENGINE ...... H.P. ...... Rated R.P.M ...... Measured R.P.M. ...... Pulley Dia. ...... Face ......
Eng. Cyl. Dia. ...... Length of Stroke ...... Kind of Fuel ...... Gals. per Hr. ......
Price of Fuel ...... I.H.P. ...... B H P. ...... Kind of Belt ...... Belt Speed Ft. per Min. ......
MOTOR ...... H.P. ...... Voltage ...... Rated R P M ...... Measured R P.M. ......
Pulley Dia. ...... Face ...... Shaft ...... Keyway ...... Serial No. ......
METER No. ...... Type ...... Amp. ...... Volts ...... Disk K. ......
Rev. ...... Sec. ...... Current Trans. Ratio ...... Pot. Trans. Ratio ...... K W Input ......
KIND OF PUMP ...... Size ...... No. of Stages ...... Shop No ......
Pulley Dia ...... Face ...... R.P.M. ...... Dia. of Impeller ......
Pump Rating ...... Width of Spreader ......
Dia. of Cylinder ...... Length of Stroke ...... Size of Rod ...... Size of Tube
No. Strokes per Min. ...... Ratio of Gears ...... Distance "C" to "C" of Pulleys ......
Depth of Pit ...... Size ...... Inside Dia. of Discharge Pipe ...... Inside Area Sq. In. ......
Vacuum ...... Measured Lift ...... Pressure ...... Total Head ......
Flow Meter Readings ...... K= ...... G P.M. ...... M.I. ...... M.I. per K.W. Input
Type of Weir ...... H= ...... L= ......
K.W.H. per M I. 24 Hrs. ...... Pump Eff. ...... Over all Eff. ...... Motor Eff. ...... Belt Loss ...
Acre Ft. Pumped in 24 Hrs. ...... K.W H. per Acre Ft. ...... % Full Load K. W. Input to Motor ......
Kind of Crop ...... No Acres under Irrigation .

Fig. 5

3-phase, with a few 2200-volt motors confined to sizes above 50 h. p. Personally we do not favor 220-volt motors in the irrigation field, except in a few special cases where they operate during both summer and winter seasons and where they are under competent supervision.

Where proper care is taken in the application of water to the crops, the duty of water in this territory ranges from 18 to 36 in. and with the present efficient pumps on the market the input should seldom exceed two kw-hr. per acre foot per foot of lift. On this basis, assuming a lift of 100 ft. and the duty of water to be 36 in., the input would be 600 kw-hr. per acre per season. At a rate of 1.5 cents per kw-hr. this would mean a cost of $9.00 per acre per season which is very reasonable.

This statement, of course, only serves the particular conditions given in this case and cannot be taken as an average condition as there are many cases where water is lifted less than 40 ft. and a few cases in the citrus fruit sections where water is lifted from 350 to 900 ft. Usually where water is lifted to the higher levels, however, the efficiency of the units is higher and a lower rate per kw-hr. is earned.

Repeated Thermal Expansions and Contractions

Their Effect on Long Armature Coil Insulations

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THERE has been considerable discussion among engineers interested in the operation of large turbo-generators as to the possible effects of expansion and contraction on armature coil insulation. During the past ten years, generators have increased in core length from less than 100 in. to 160 in. and generators approaching 200 in. in core length are being discussed. With increasing length of cores, it has become more important to settle this question and the tests described in this paper were undertaken three years ago with this object in view. Preliminary tests were started on May 5, 1921, in order to work out some of the details of the procedure. The investigations herein described were actually started on June 2, 1922, the test coils having been prepared just previous to that time.

That some differential effect may reasonably be expected in long-core generators arises from the fact that the coefficient of thermal expansion of built-up mica and paper insulation is practically the same as that for iron[1] while the coefficient of copper is roughly 50 per cent larger. With a core length of 150 in. and an average temperature difference between copper and core teeth of 40 deg.—a usual value for high voltage windings—the difference in linear expansion between core and insulation, on the one hand, and the copper of the coils, on the other hand, will be roughly 1/32 of an inch.

Description of Apparatus and Procedure

A set of four slots was made up from punchings such as is shown in the upper part of Fig. 1. The slots were of sufficient depth to permit two insulated coils to be placed and wedged in each slot. The punchings were assembled in two sections each 54¼ in. in length including the two ⅛ in. end plates. These two sections were then placed end-on and bolted tightly together so as to constitute four slots 109¾ in. long and having the imitation vent ducts as indicated in the lower sketch of Fig. 1. There were six ½-in. imitation vents at the one end of the assembled slots; another six ½-in. vents near the middle, and three 1¼ in. vents near the middle. The positions of these vents are given on Fig. 1.

The experimental coils each had 8 square brass tubes ¼ in. by ¼ in. for conductors. Six sets of these 8 tubes were assembled into coils and insulations for a length of 118 in. with standard Westinghouse insulation for 13,200 volts according to the standard Westinghouse practise. Slight variations were made in applying the insulation in certain cases, in that the quantity of mica was varied and also in impregnating the assembled conductors before applying the insulation so as to produce a sort of slip joint. The other two coils were insulated with mica tape instead of with the regular turbo-coil insulation.

Eight thermocouples were placed with their junctions adjacent to the various conductors on each coil. There was one couple placed on each tube. There were two of these couples placed at the mid-point of the length of the coil and others at intervals of 17 in. in either direction from the middle towards the ends. These couples were

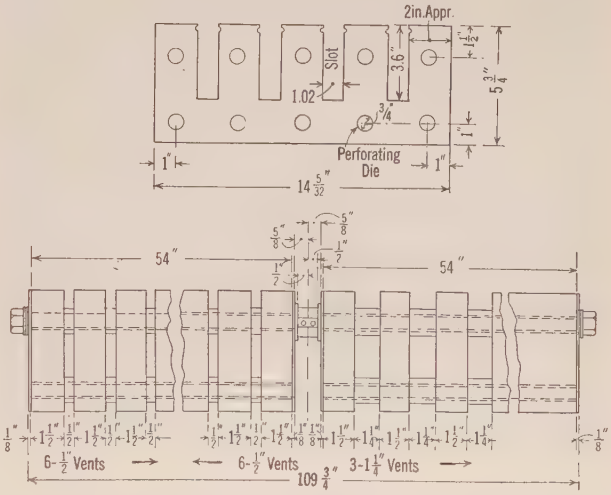

Fig. 1—Experimental Punchings for Expansion Test

made of 0.005 in. advance and copper ribbon being insulated with mica tape.

The coils after being insulated were inserted into the slots and wedged into place by the standard methods. Two coils, one over the other, were placed in each slot. The conductors of the coils were joined electrically in series. They were also joined by means of rubber tubes in parallel to air reservoirs, which were connected in series with a blower and valve. It was possible by means of the blower and valve to cool the coils by air circulation and to reverse the direction of the air through the tubes during the cooling period. The general set up is shown in Fig. 2. Some of the auxiliary apparatus used is indicated by letters on Fig. 2 and noted on the description below the figure.

The heating of the coils was produced by means of alternating current supplied by a suitable transformer.

1. This coefficient was determined by O. H. Gish of the Westinghouse Research Laboratory for Westinghouse micarta folium insulation during the early part of 1921.

Presented at the Northeastern District Regional Meeing of the A. I. E. E., Worcester, Mass., June 4-5, 1924.

The time the current was on, the starting of the blower, the reversals of the air stream or operation of the air valve, and the stopping of the blower were all controlled by means of a time contact-making device. This was so adjusted that one complete heating and cooling cycle occurred in one hour in the early experiments. In the latter part of the tests this cycle was completed each 50 min. This was the case as a result of the characteristics of the contacting device. In the early part of the tests the length of the times of heating, and cooling, and the magnitude of the heating current were so adjusted that the temperature of the conductors would reach 150 deg. cent. at their mid-points during the heating cycle, and would be cooled to approximately 100 deg. cent. during the cooling part of the cycle. The temperature of the iron stampings constituting the slot formation was so adjusted that it was approximately 100 deg. cent. This was accomplished by means of placing insulating materials over the form. Two sheets

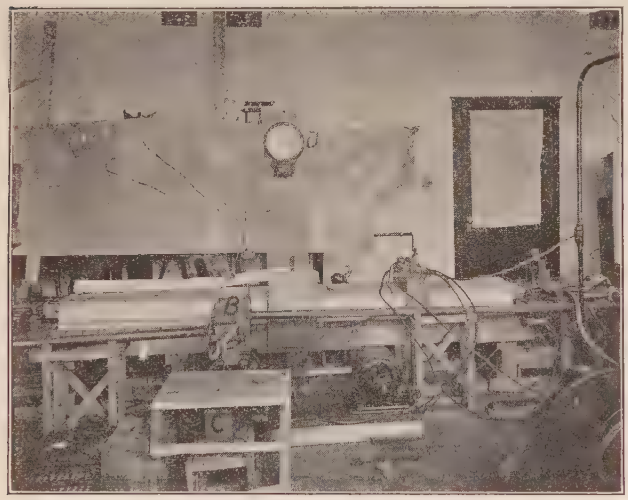

Fig. 2—Long Coil Insulation Expansion Contraction Destructive Tests

A —Blower
B-C—Air Valve for Reversing Direction of Air Flow
D —Recording Thermometer Used to Check Air Reversals

of regular thin sheet asbestos were found to be sufficient for this purpose.

The temperature distributions along the stampings and along the conductors before and after cooling are shown in Fig. 3. This curve shows an average temperature drop of the conductor during the cooling cycle of approximately 50 deg. cent.

The heating current was then adjusted so that this average drop in temperature of the conductors was 75 deg. cent. This particular change of temperature was such as to produce as much differential change in expansion and contraction as would be produced when a machine having coils of the length used in these tests would cool from maximum operating temperature to room temperature. The average change of 75 deg. cent. in temperature of the conductors of the coils was continued for approximately 7800 heating and cooling cycles. The insulations of the coils then still having withstood an insulation voltage test for one minute of 23,000 volts, the heating current and cycle were so changed as to obtain an average temperature change of 100 deg. cent. in the temperature of the conductors. This temperature change was continued for approximately 2500 more cycles, thus making a total of 10,300 heating and cooling cycles since the beginning of the

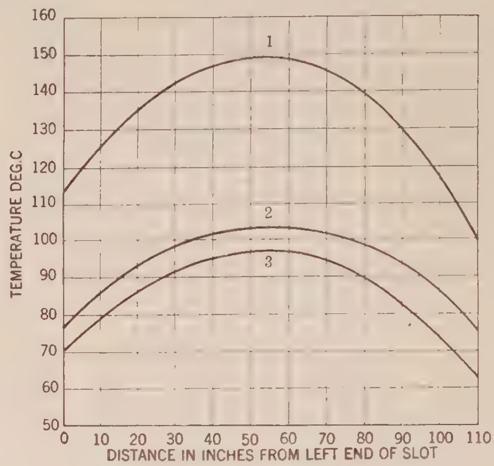

Fig. 3—Temperature Distribution Curves

1—Along Conductor before Cooling
2—Along Slot or Iron Stampings
3—Along Conductor after Cooling

test. The insulations still standing a voltage test of 23,000 volts for one minute, it was decided to still increase the temperature change of the conductors during the cooling cycle. To do this it was necessary to substitute water-cooling in the conductor tubes in place of the air-cooling. For this substitution, a magnetically-operated water valve was substituted for the magnetically-controlled air valve used up to this time.

Conditions of heating and cooling were so adjusted

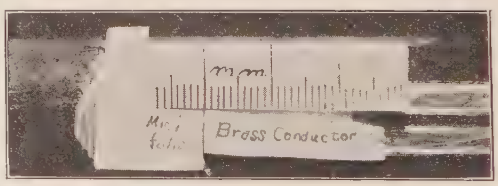

Fig. 4—Relative Positions of Conductor and Insulation at Close of Cooling Cycle

that an average temperature change of the conductors of 130 deg. cent. was produced during the cooling part of the cycle. Such a change in conductor temperature was continued for approximately 825 cycles. The range of temperature change of conductors was then further increased to approximately 160 deg. cent. and was continued for approximately 400 cycles. At this point in the tests, the transformer furnishing the heating current failed on Feb. 8, '24. The coils were tested for breakdown and after removing several inches of the

stampings from the ends of the form constituting the slots, in order to prevent sparking over the ends, it was impossible to break down the insulation of any one of the 8 coils with a voltage of 37,000. So much difficulty was encountered in preventing sparking over the ends for any higher voltage, that 37,000 was as high as was used in testing the insulation at the completion of the test.

An idea of the relative change in length of the coil insulation and the conductors during a heating and cooling cycle can be obtained by referring to Figs. 4 and 5. Fig. 4 shows the positions of the brass conductors and insulation at the close of a cooling cycle, and Fig. 5 at the close of the heating part of the cycle. These show a relative change in length of conductor and insulation of almost 5 millimeters (0.197 in.) at each end of the coils. These illustrations were made during the latter change of 160 deg. cent. of the conductors during the cooling cycle.

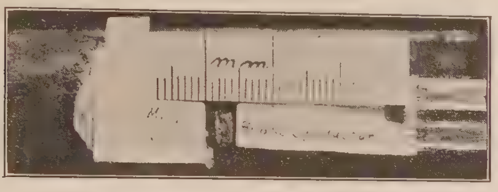

Fig. 5—Relative Positions of Conductor and Insulation at Close of Heating Cycle

The following summary gives the number of cycles, the corresponding temperatures of coils at end of heating periods of each cycle, and the temperature change in the conductors during the cooling part of the cycle, as well as the temperature of the iron stampings constituting the slots.

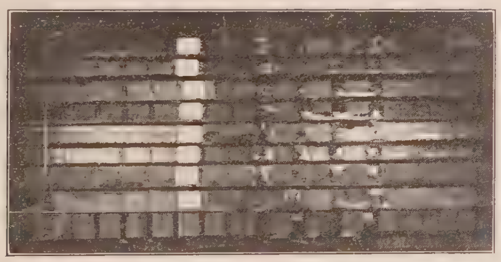

Fig. 6—Illustration of Middle Portion of Coils After Completion of Tests and Removal from Slots. Also Showing Imitation Vent Ducts in Stamping Form Constituting Slots

Tem. of Coil at end of heating Cycle	Temp. Drop during Cooling of Conductors	Tem. of Stampings	No. of Cycles for Temp. Range	Total No. of Cycles
150 to 160 deg. cent.	75 deg. approx.	100 deg. approx.	7800	7,800
160 to 170 deg. cent.	100 deg. "	100 deg. "	2512	10,312
150 deg.	130 deg. "	100 deg. "	825	11,137
180 deg.	160 deg. "	100 deg. "	400	11,537

After the completion of the 11,537 heating and cooling cycles and the failure of the transformer supplying the low-voltage heating current, the coils were removed from the slots and examined. Fig. 6 shows the eight coils after their removal from the slot. It is quite evident from this illustration that the paper cells which were put around the coils are completely carbonized at the middle portion of all the coils. The two coils insulated with mica tape were naturally more difficult to remove from the slots. In fact, the others were removed with considerable ease as they only bound slightly at the imitation vent ducts where the insulation had swollen slightly.

Discussion of Results

The eight samples of long coil insulation have successfully withstood the severe tests resulting from long continued heating and repeated heatings and coolings of the conductors. The range of temperature change was at first made such as would be equivalent to the differential effect produced as a result of the different coefficients of expansion of iron stampings, insulation, and brass conductors. This range of temperature change was continued for 7800 cycles, which would be as many such changes as the machine would possibly have in practise by warming up and cooling down once each day for almost 22 years. The coils were subjected to a one-third greater relative change for an equivalent of some 7 years possible heating and cooling changes. The cooling by means of water for 825 cycles and 130 deg. cent. change in conductor temperature, and for 400 cycles and 150 deg. cent. was extremely severe treatment, in that the relative changes were approximately twice as much as would be experienced in practise. These tests having extended over a period of about 20 months and the coils having been subjected to such severe treatment without failure even at 37,000 volts at the completion of the tests, indicate that all the samples of insulation were of excellent quality from both a mechanical and an electrical standpoint. Inspection of the coils after removal from the tests disclosed no places where the insulation had been sufficiently bent or folded at any vent duct so as to produce any cracking of the insulation. If such had been the case, a voltage of 37,000 would have broken down the insulation at any such points.

It might be well to mention the fact that these samples of insulation were even subjected to more severe treatment on several occasions than is to be inferred from the discussion thus far. These cases arose when the contacting device failed to operate properly at some 8 or 10 different times and thus permitted the heating current to be left on the circuit continuously and no cooling to be produced for some six or eight hours before it was discovered. At such times the temperatures of the conductors may have reached values as high as 250 deg. cent. and the iron stampings a temperature of 135 deg. cent. By looking at the coils,

it is apparent that quite high temperatures have been reached at times on account of the darkened, in fact blackened, condition of the paper, in particular at the vents in the external part of the wrappers. The discoloration was much more pronounced naturally at the middle point of the coils than at the ends. The discoloring seemed to be more pronounced on the coils which were in the lower portion of the slots as might reasonably be expected. While the paper in the insulation had very little mechanical strength left, the insulation as such was sufficiently strong mechanically to retain its form about the conductor and suffer no apparent additional destructive effect during the removing of the coils. The deterioration was very much more marked at imitation vent ducts than where it was in contact with the stampings. The paper was only just browned instead of blackened where the coil was adjacent to the stampings. The deterioration was much more pronounced also at the 1¼-in. vent ducts than at the ½-in. ducts. This is what might be expected since the wider the duct, the more readily could the air reach the paper and thus produce the effect.

Current-Limiting Reactors

BY W. M. DANN

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Review of the Subject,—*Current-limiting reactors are desirable only insofar as they are strictly reliable protective devices. In this paper general considerations of the factors affecting reliability are outlined, and some of the early weaknesses and the means taken to eliminate them are enumerated. Modern reactors are considered to be reliable and on large systems are considered practically indispensable.*

The thermal duty of a current-limiting reactor is a consideration affecting the reliability which has been the subject of considerable discussion. Various opinions have been expressed ranging from the idea that a reactor should fail first and open the circuit in the event of short circuit, to the idea that it should have enough thermal capacity to withstand short-circuit currents for long periods of time. A middle ground is suggested in this paper where recognition is given both to the protective function of the reactor and to the practical consideration of dimensions and cost.

GOOD voltage regulation was the aim of the electrical engineer in the early days when generating units and systems were small compared with those to which we are now accustomed. Low power factor was the great influence which operated against this ideal. Reactance was the element that produced low power factor. Consequently, reactance was a thing to be eliminated as far as possible.

When generating units and transmission systems became larger and more extensive, voltage regulation began to be of somewhat less importance. The heavy currents developed at times of short circuit became a matter of concern. Gradually reactance began to be recognized as the solution for preventing destructive short-circuit currents and the present extensive use of the current-limiting reactor is a natural accompaniment of the growth of the modern power system.

The reactor is a desirable thing only insofar as it is a strictly reliable protective device. Its cost and its energy losses are undesirable and it takes up valuable space. Moreover, the very magnetic field which is depended upon for it to function may be the cause of troubles in operation. Service experiences, however, in the past few years have enabled manufacturers to offer reactors that are entirely reliable and in large generating systems they are practically indispensable.

Early Installations

The first example of current-limiting reactors, or "choke coils," placed in the circuit to guard against the destructive effects of heavy short-circuit currents, was in the Cos Cob Station of the New York, New Haven & Hartford Railroad, as far as the author's recollection goes. These coils were built by the Westinghouse Electric & Mfg. Co. and were put into operation in 1908 to protect the generating units. Little or nothing was known at that time about the practical design of air-core reactors, while the reactance determination of generators was very well understood. As a result, these first coils were made with an iron core and with very large air gaps which again were similar in general form to the small air gaps of a generator. The punchings were made up with slots to receive the coils, which were very similar to those used in a generator armature. The iron part of the magnetic circuit was worked at a very low normal density, in order to keep the density in the core below the saturation point under short-circuit conditions. As a result,

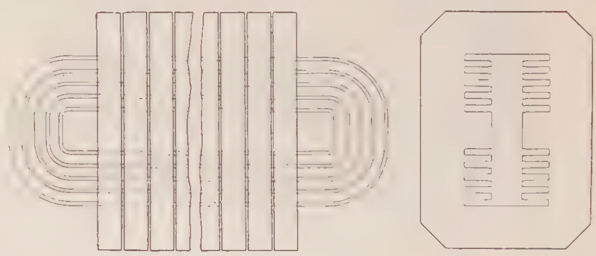

Fig. 1—Iron-Core Current-Limiting Reactor Used by the New York, New Haven & Hartford Railroad in the Cos Cob Station

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

these reactors gave a practically straight line voltage characteristic from no-load current up to the short-circuit current. The general construction of the reactor is shown in Fig. 1.

The second installation of current-limiting reactors, as the author remembers it, was made by the Commonwealth Edison Co. of Chicago. These coils were built by the General Electric Company. No magnetic material was used in their construction. They were made up of bare stranded copper cable wound in cylindrical form on a concrete core with the layers spaced by means of treated wooden strips.

General Considerations

When engineers first turned their attention to the problem of providing inductance for current-limiting purposes, it was realized that the reactor would be subjected to high electrical and mechanical stresses when short circuits occurred. It was appreciated that on account of its concentrated inductance, high-frequency disturbances would throw great voltage stresses on the reactor, especially on its end turns, but the real magnitude of these stresses was more or less unknown.

It was also recognized that the mechanical stresses in a current-limiting reactor would be very large, on account of the extremely large number of concentrated ampere turns under short-circuit conditions. Mechanical stresses vary with the square of the ampere turns and they depend upon the degree to which these ampere turns are concentrated or broken up into groups. In a generator, the ampere turns are distributed over the entire periphery of the armature. In a transformer they are broken up into a number of groups and in the primary and secondary groups these ampere turns cancel each other to a very large extent, since the currents are in opposite directions in the high-tension and low-tension windings. In a current-limiting reactor, however, the current flows in only one direction and the ampere turns are very highly concentrated, resulting in mechanical stresses of enormous magnitude.

These forces are in such a direction that the tendency is to make the coil enclose a greater total flux, that is, they tend to increase the diameter of the coil and shorten its axial length. The forces tending to increase the diameter produce a tensile stress in the conductors of the coil. The tendency to shorten the axial length creates a compressive stress on the spacers between the conductors and bending stresses in the conductors themselves.

The strong magnetic field that permeates the coil, due to the large number of turns in the reactor, would produce prohibitively large losses within the conductors if special precautions were not taken to guard against them. A solid conductor, for instance, would give rise to very great eddy current losses within it and these losses would multiply rapidly if the diameter of the conductor were to be increased. For these reasons, a finely stranded cable is the obvious conductor for a current-limiting reactor and the smaller this cable can be made practicably, the better is the conductor from the point of view of low eddy current loss.

Using a small cable requires that a number of them be employed in parallel for currents greater than the capacity of a single conductor. The danger of paralleling circuits in the presence of a strong magnetic field, varying in intensity at different points, will immediately be apparent to one having experience in such matters. In order to avoid unequal division of current or circulating current in the cables, the Westinghouse Company uses a special method of winding for paralleled cables, whereby each conductor passes through a series of positions with respect to the magnetic field which are exactly duplicated for every other conductor in parallel with it. This is accomplished by transpositions in the slots when winding.

As an illustration of this method of winding with two cables in parallel, one cable is carried around one-half the circumference of the inner row of slots in the first layer, and at that point transposed to the next row of slots. The second cable is started at this point in the inner row of slots and is carried around through the second half of the circumference. Consequently in the circumference of the inner row of slots the two cables pass through positions in the structure which are identical with respect to the magnetic field and they are exposed to the same integrated magnetic conditions. This method of easy transpositions from one row of slots to the next is carried out through the entire structure and the condition of equal resistances and equal inductances in the parallel conductors is accomplished. Unequal division of current in the paralleled paths is in this way effectively eliminated. This method of winding may be employed for any reasonable number of cables by making the number of columns of cleats a multiple of the number of cables used.

The strong magnetic field also causes magnetic forces between adjacent conductors in the winding, especially those close to the top and bottom of the coil where the accumulative effects are greatest. These forces are guarded against by placing the spacer supports between conductors close enough together to keep the maximum forces within the strength of the conductors. Shortening the length of the span between supports must not be carried too far, however, for the greater the number of supports, the less is the radiating surface of the conductors and the higher the operating temperature. The size of the conductors and the arrangement of the structure used must be selected to give full consideration to both of these conflicting factors.

A fairly high operating temperature is permissible, considering the fireproof construction of the modern current-limiting reactor. However, the operating temperature at normal current is often of minor importance

compared to the temperature reached during short-circuit conditions. When a very heavy current flows for a short time, the copper must store up the vastly increased energy loss and it appears as a rapidly increasing temperature. The structure in supporting the cables must for this reason provide for the expansion of the conductors at the time of short circuit.

The thermal duty of a reactor can best be appreciated by considering a specific case, for instance, a coil having a reactance of three per cent under normal conditions. Under short-circuit conditions, assuming no other reactance in the system, this coil would carry 33⅓ times its normal current. The thermal results, like the mechanical stresses, vary with the square of this current, and the temperature will immediately start toward the point corresponding to something over 1000 times the normal heat units. While this rapid increase of temperature lasts over only a comparatively short period, the temperature reached at the end of the period is often the determining point in designing a reactor from the point of view of heating. The 5 per cent reactor would be designed with a higher normal operating temperature than the three per cent coil, for the heat units developed in such a coil at the time of short circuit, again assuming no other reactance in the system, would be 400 times normal rather than 1000 times. Consequently, it is reasonable to neglect the normal operating temperature in writing specifications for current-limiting reactors, except in cases of reactors for a high value of inductance where the short-circuit current is not a great many times the normal current. The designer's chief interest in the normal operating temperature relates usually to its effects on the temperatures reached under short-circuit conditions.

There are various viewpoints among engineers as to the length of time during which a current-limiting reactor should carry short-circuit current without failure due to excessive temperature.

The extreme point of view in one direction would be that the reactor should be the weak link in the chain and, like a fuse, should fail and open the circuit before the other apparatus can be affected. Most engineers will agree that the premeditated interruption of a heavy alternating current by means of the failure of a highly inductive device like a reactor would be an undesirable thing.

An extreme view in the other direction is that the reactor should have thermal capacity in such abundance that it can withstand its short-circuit current for a period as long as ten minutes. The point of view for such an opinion is based on disturbances of record which have lasted even longer than ten minutes before the source of the trouble has been found. Reactors designed with such thermal capacity would be so expensive and would occupy so much space that they probably would not be found practicable.

Between these two viewpoints is a middle ground where recognition can be given both to the protective function of the reactor and to the practical considerations of dimensions and cost. The maximum current that can flow through a reactor is that which would obtain if full line voltage were applied across its terminals with no other impedance in the circuit. If a reactor were required to withstand such a current for a period of five seconds, it would represent a fair compromise between the cost and dimensions of a reactor having greater thermal capacity and the protection which such a period of time would provide for the system.

The First Westinghouse Reactors

The reactors illustrated in Fig. 2 are typical of the first of the air-core current-limiting reactors built by the Westinghouse Electric & Mfg. Co. in 1913. They were wound in the form of a cylindrical coil with pancake layers of bare stranded copper cable laid in grooved spacers of treated hard wood. The columns formed by these spacers were bolted together with

Fig. 2—The First Westinghouse Air-Core Current-Limiting Reactors

brass tie rods. Insulating supports or feet at the bottom and a terminal board at the top completed the structure. Ordinary transformer practise was followed in designing the terminal board, except that greater spacing was provided between the terminals than was used in transformer practise. The conductors were soldered into the terminals which were clamped between nuts at the lower end of the studs shown in the illustration. Fig. 3 shows the coil partly wound.

It is clear now that the type of construction used in these original designs was fully strong enough to withstand the mechanical shocks of short circuit. Rather elaborate factory tests were made shortly after the first coils were built in an effort to find out whether the limit of mechanical strength of these coils could be reached.[1] A 15,000-kv-a. generator was short-circuited a number of times with increasing excitations with a single reactor in circuit and again with a bank of three reactors, and tests made to the limit of the generator excitation failed to find any weaknesses in the design. Large short-circuit currents were produced

1. *Electrical Journal*, Vol. 11, April 1914, pages 188 to 207.

during these tests and the magnetic forces within the reactor were correspondingly high. For determining the fitness of the design for service on a very large system, such tests are necessarily inconclusive, but service records since that time have abundantly proven that the design is adequate, at least for short-circuit currents as we know them up to the present

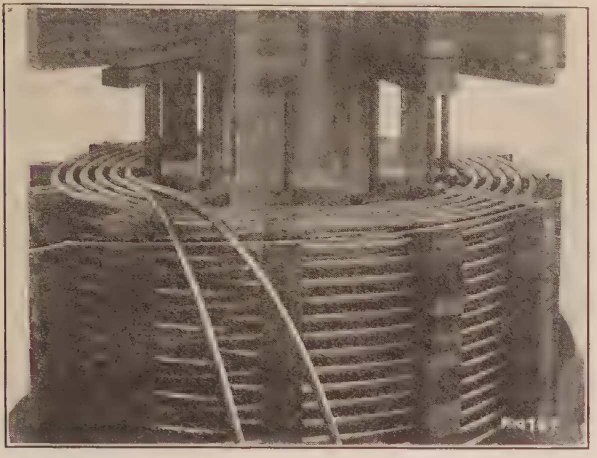

Fig. 3—Showing Method of Winding the Reactors of Fig. 2

time. The same general arrangement of windings and structure has been used ever since by the Westinghouse Company.

Troubles that have occurred in service have been due mainly to an under-estimate of the excessively high transient voltages that are set up by disturbances

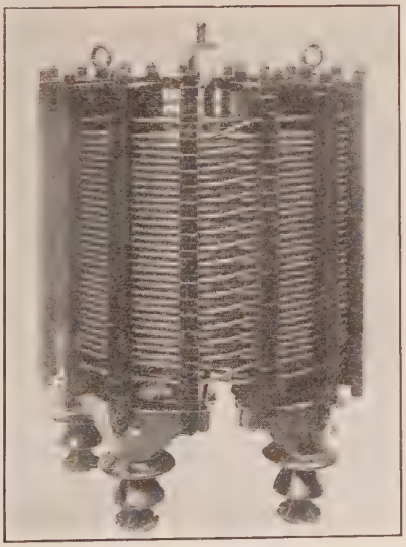

Fig. 4—A Modern Westinghouse Current-Limiting Reactor

in the system and of their effects when concentrated upon the reactor. It was very soon found that these voltages must have been as high as 50,000 volts across the reactor when connected in a 11,000-volt circuit, judging from the distances over which they jumped. This voltage manifested itself principally across the end turns of the coil and across the terminals when they were placed together at one end of the reactor, as in the original coils, Fig. 2.

Another trouble early encountered was found to be

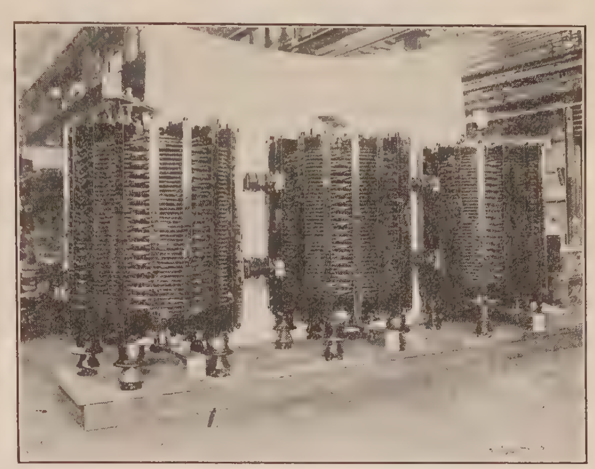

Fig. 5—Single-Phase Reactors in a Three-Phase Bank, Braced to Withstand Forces of Attraction Between Units

due to the metallic tie rods used to clamp the columns of spacers. Surge voltages found a path from conductors at one end to conductors at the other end across the spacers and through these metallic rods, thus short-circuiting the coil.

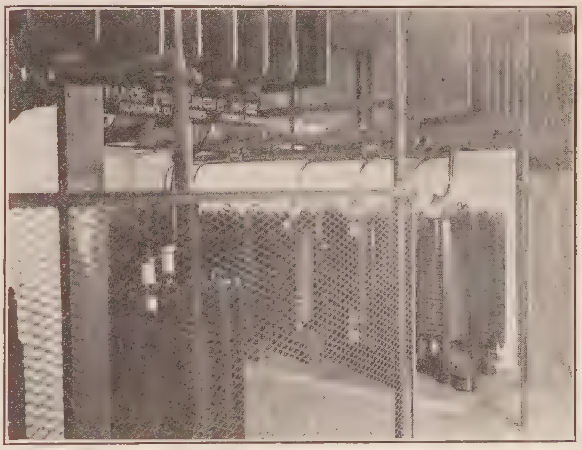

Fig. 6—An Installation of Reactors

A few cases of mechanical weakness in the insulating feet and of flashover to ground of insulators that were inadequate also occurred. Trouble of a different kind developed in one or two instances due to soldered terminals which failed and opened up the circuit within the reactor, causing considerable burning due to arcing.

One by one all of these weaknesses have been eliminated. Through the troubles which have occurred in service, the modern reactor has been developed to the point where it is a protective device having the me-

chanical sturdiness and the electrical strength to carry out its function successfully and to justify its use.

Summary of Elements of Design of the Modern Westinghouse Reactor

The principal elements that contribute to the strength and efficiency of the modern reactor may be briefly summarized as follows:

1. Finely stranded cables of small diameter keep to a minimum the stray losses within the conductors due to the magnetic field. Paralleled sections of windings are used where necessary to carry the current and retain this feature. By reason of the special method of winding, these paralleled lengths of cables have the same resistances and the same inductances, and extra losses, due to unequal division of current, are eliminated. As a final finish, the complete reactor is dipped and baked a number of times in a fire-resisting enamel. This enamel permeates the strands of the cable and helps further to reduce the stray losses. It also serves to stiffen the conductors and give them greater mechanical strength.

2. Extra spacing of end turns eliminates danger of flashover, due to high-frequency transient voltages at times of disturbances on the system.

3. Fire proof composition spacers molded under great pressure form the supporting structure. The slots into which the cables are laid in the winding operation provide sufficient clearance to permit expansion of the copper, due to the rapid heating at the time of short circuit. Wood rods of treated straight-grained hickory are used to clamp the columns of spacers together. Being entirely enclosed in the fire-proof spacers, these wooden rods do not form an inflammable element.

4. One terminal is placed at one end of the coil and the other at the opposite end to eliminate the danger of flashing across terminals.

5. Normal current densities are set low enough to keep temperatures within safe limits when the sudden heating, due to heavy short-circuit currents, develops.

6. Solderless clamped connectors are used to connect the ends of the winding to the terminals. Contact nuts, made with a lug having a radial saw-cut through it, are arranged so that they can be bolted after being tightened. Once set, they are permanently locked in position. Brass tubes placed over the leads between the winding and the point of connection to the terminal studs give the necessary stiffness to these leads to eliminate troubles due to mechanical forces exerted on them when heavy short-circuit currents flow.

7. Extra heavy pin-type or pedestal-type insulating supports give the necessary mechanical and electrical strength to eliminate troubles due to mechanical breakage or to flashover to ground.

Figs. 4, 5 and 6 illustrate examples of modern Westinghouse current-limiting reactors.

RADIAL CURRENTS NON-INDUCTIVE

By Carl Hering

According to laws as taught at present, if the writer (and some others) understand them correctly, when electrons travel from the center of a circular disk to the circumference (or the reverse) they will not encounter any self-inductance in this radial path. Hence such a one-way circuit is non-inductive, which seems to mean that no flux is generated. Hence, even if the current is very large, a magnetic needle placed in close proximity to such a disk would not show any deflection. It would be a curious case of a uni-directional current without any magnetism.

Such a case might arise in practise if a bolt of lightning entered a horizontal moist stratum and distributed itself radially; there would be no inductance in the radial part of the circuit.

Upholders of the older theory that electrons cannot move from one point to another unless there is a "complete circuit," will of course say, "where is the rest of the circuit." Some juggling would be necessary to answer this in the case of a bolt of lightning; and that favorite subterfuge, the "sliding contact" cannot be called to the rescue. Another answer would be to consider the rest of the circuit as being infinitely far removed so that its effect would be mathematically zero. But this may lead to the serious pit-falls into which mathematicians have fallen, as was so ably discussed by Dr. Mailloux (A. I. E. E. Journal, Nov., 1923, p. 1186 beginning at bottom of first column.)

In the laboratory the conditions might be approximated by making one conductor a large tube closed at one end by a disk, from the center of which there is a conductor in the direction of the axis of the tube, as a continuation of it, on the outside, of course. According to our present theories a magnetic needle close to the inside surface of the disk ought to show no deflection whatsoever no matter how strong the current; and on the outside it should deflect exactly as much as it would if far removed from the disk but held at the same radial distance from the axial conductor; that is, the flux on the outside of the disk is that due entirely to the electrons in the axial conductor and not to those much nearer to it in the disk.

The experiment seems worth trying. If our older laws should need to be repaired, in the light of modern developments, the sooner we know it the better, especially for the rising generation.

TESTING OF CURRENT TRANSFORMERS

The number of current transformers tested during the past fiscal year at the Bureau of Standards was over four times the average number submitted during the preceding six years. The reason for this sudden increase originates in a new method for the testing of this class of apparatus in the field. This method was invented at the Bureau of Standards and has been incorporated in a convenient testing set.

Obtaining Steady High-Voltage Direct Current
From a Thermionic Rectifier Without a Filter

BY F. W. MAXSTADT

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Review of the Subject.*—The usual polyphase high-voltage rectifier produces a potential essentially constant but having superposed on it a "ripple" or alternating component whose amplitude on each side of the mean is from five to seven per cent of the total d-c. voltage. Condensers and reactors are used to filter the ripple out. The paper describes a special type of a-c. generator which will give the proper low-voltage wave form for rectification as a more nearly smooth direct potential. A method of manually or automatically varying the low-voltage wave form according to load demands is provided so as to keep the rectified potential steady, thus avoiding the necessity for the filter which in sets for 100,000 volts or more would be quite expensive and troublesome.*

INTRODUCTION

MANY types of circuits have been suggested and used for stepping up a sine wave single or polyphase low-voltage alternating current and then rectifying by means of either a synchronous commutator or one of the forms of electric valve. The resultant unidirectional potential and current have an alternating component which must usually be considered, and in many cases, eliminated to a fraction of a per cent before the high voltage direct current is suitable for the desired purpose.

The apparatus which suppresses this alternating component, the filter, consists of a condenser or set of condensers suitably connected with reactors and tuned to draw a large current at the principal frequency of the undesirable alternating component wave, *i. e.*, the sixth harmonic of the fundamental impressed on the low-voltage side of the rectifier. For voltages up to 15,000, such a filter is a fairly easy problem, but for 100,000 volts or more, the condensers become bulky and expensive.

In order to avoid the necessity for a filter, the wave form of the alternating potential impressed on the transformer low side must be of special shape. It is proposed to outline here the features of a special generator which employs straight forward methods of altering the field distribution as the load requires and which has a distributed armature winding capable of generating the desired wave form at no-load when the field distribution is uniform under the pole face.

THE GENERATOR

A three-phase Y-connected winding has voltages across its terminals which are the instantaneous *differences* of the component leg voltages and it will be seen by an inspection of the ideal diagram, Fig. 1, that by generating a triangular wave in each leg of the Y, a flat-top wave, horizontally flat for 60 electrical degrees of every half cycle, results. Furthermore, the flat top wave coming from a Y-connection contains no third harmonic or its multiples. It may therefore be used equally well in a Δ- or a Y-connected transformer bank. The triangular wave contains theoretically, in addition to the fundamental, 11.11 per cent third harmonic, 4 per cent fifth, 2.04 per cent seventh, 1.235 per cent ninth, 0.828 per cent eleventh, etc. The fraction representing the harmonic amplitude is $1/n^2$ of the fundamental amplitude, where n is the number of the harmonic. Even harmonics are absent. The flat top wave contains theoretically, no third harmonic, 4 per cent fifth, 2.04 per cent seventh, no ninth, 0.828 per cent eleventh, etc. Even harmonics and multiples of three are absent.

Mechanically, the generator has a 50 per cent pole arc and a coil span of 50 per cent, the turns being full or fractional pitch according to other considerations. Thus the generated voltage in one leg of the Y is zero only when the armature coils are all in the interpolar space and maximum only when they are all under the poles. Intermediate voltages are proportional to the number of conductors under the pole, and hence proportional to angular displacement from a reference point. This forms a triangular wave. The other necessary conditions are: no flux fringing at the pole tips and uniform distribution under the poles. How closely these conditions can be met experimentally is shown by the oscillogram, Fig. 2. The top curve shows generator terminal voltage, the middle curve transformer exciting current on the

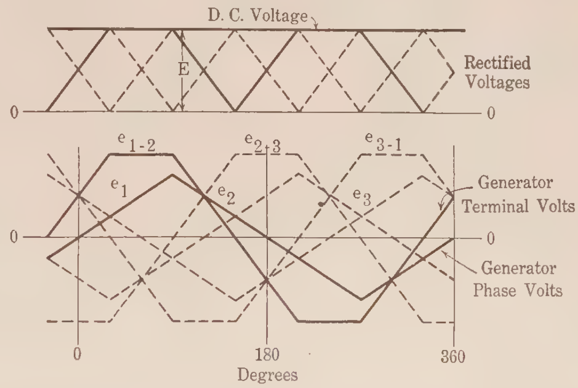

FIG. 1—THEORETICAL DIAGRAM OF VOLTAGES IN THE VARIOUS CIRCUITS OF GENERATOR AND RECTIFIER

E = D-c. voltage

$e_1 = 0.607\ E\ [\sin \omega t - 1/9 \sin 3\ \omega t + 1/25 \sin 5\ \omega t - 1/49 \sin 7\ \omega t + 1/81 \sin 9\ \omega t - \ldots]$

$e_{1-2} = 1.051\ E\ [\sin (\omega t + \pi/6) + 0 - 1/25 \sin 5 (\omega t + \pi/6) + 1/49 \sin 7 (\omega t + \pi/6) + 0 - 1/121 \sin 11 (\omega t + \pi/6) + \ldots]$

Presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17, 1924.

flat-top wave, and the lower curve, voltage on one leg of the generator.

The experimental generator was a rebuilt Crocker-Wheeler bipolar 10-kw. d-c. machine having a smooth core, 8-inch diameter, armature, and 3/8-inch air gap. The armature was specially wound as described above. The field poles were cut away to suit, and a pole face

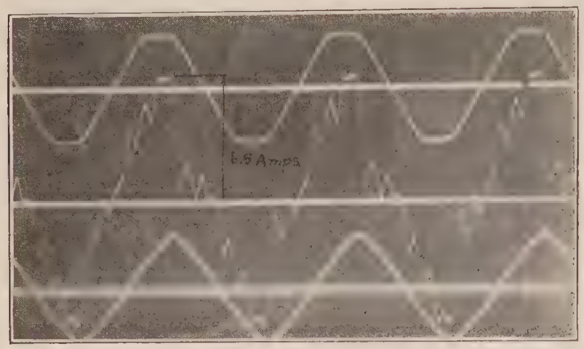

Fig. 2—Voltage Wave Forms on the Special Flat-top Wave Generator

Upper curve—Terminal voltage (load consists of exciting current on $\Delta - \Delta$ transformer bank only)
Middle curve—Exciting current, Transformer No. 1
Lower curve—Voltage of one leg of generator

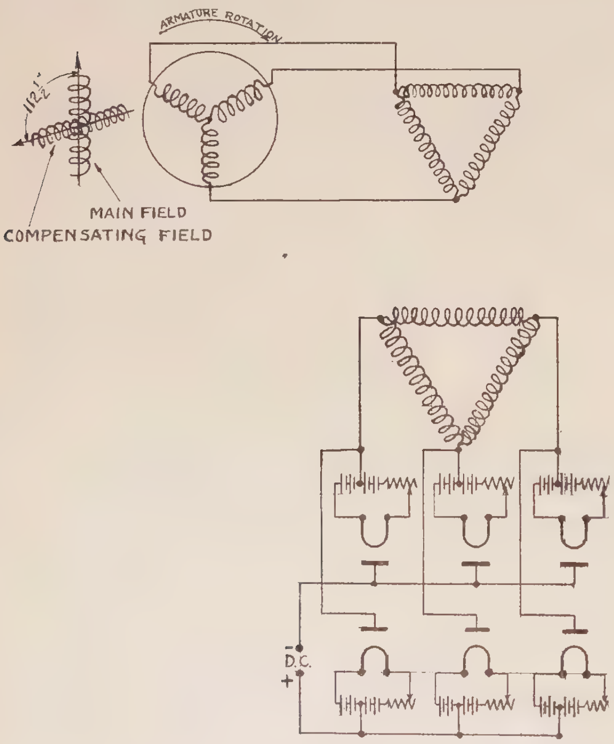

Fig. 3—Diagram of Generator, Transformer Bank, and Rectifier, Showing the Six Kenotrons with Storage Battery Excitation for the Filaments

"compensating" winding inserted to control the flux distribution under load conditions.

Compensating Winding

The pole face winding is d-c. excited, corresponding to one of the methods of controlling field distribution on a d-c. generator for purposes of improving commutation. On account of the small pole arc, armature reaction is not as bad in this type of generator as in standard generators. Also the nearly unity power factor characteristic of the load makes armature reaction largely cross magnetizing. The compensating winding ought therefore to have its field axis at right angles to the main field axis. A modification of the above theory results from the intermittent manner in which the load is suddenly applied to and then removed from the transformers by the rectifier. Distributed secondary capacitance likewise influences the current wave drawn by the transformer. It was found necessary to shift the axis of the compensating winding about 22½ deg. beyond the ideal 90-deg. position, moving it against rotation. (See Fig. 3). The effect of this shift is to tilt the top of the voltage wave away from the horizontal, causing it to rise on the leading end from 5 to 30 deg. The necessary tilt is greater when a $Y-Y$ transformer bank is used than with a $\Delta-\Delta$ bank. Thus it will be expected that more ampere turns of compensating field are needed for the same

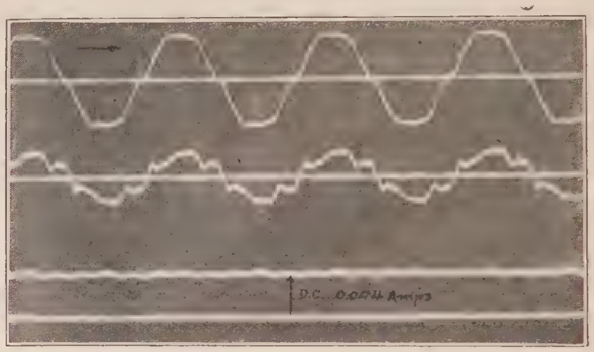

Fig. 4a—Direct-Current Characteristics of the Rectifier
Upper curve—Transformer impressed voltage ($\Delta - \Delta$ bank)
Middle curve—Current in transformer low side
Lower curve—D-c. in a water tube resistance having neither inductance nor capacitance

generator load when the former connection is used. The necessary compensating current varies approximately directly with the load and can be manually adjusted or automatically controlled by means of a regulator.

Transformers and Rectifier

It is evident that the generator must be Y-connected because of the large third harmonic in its phase voltage wave. Generator terminal voltage will then contain no third or its multiple harmonics, and may supply either a $\Delta - \Delta$ or a $Y - Y$ transformer bank. Fig. 3 is a diagram of connections using the $\Delta - \Delta$ arrangement. A $Y - Y$ bank may be substituted without other change. Special six-phase connections may also be used if desired, so long as the flat-top wave form is preserved. The rectifier consists of six standard 100,000-volt, 200-milliampere Kenotron tubes with storage battery excitation for the filaments. (Regular high-voltage filament transformers are to be preferred for continuous operation). A 51-cycle flat-top voltage was impressed on the transformers.

Experimental Results

Rectification of 100,000 volts and 50 milliamperes, 5 kw., was accomplished, limited by the 7½ h. p. driving motor on the generator, and the transformer bank, although the Kenotrons were capable of 20 kw. output. Fig. 4A, showing impressed voltage and current on No. 1 transformer and d-c. current in a water resistance, has a maximum variation of 4.4 per cent on each side of the mean. This was for a $\Delta - \Delta$ connected transformer bank. The efficiency from the transformer input to the d-c. output, neglecting 810 watts filament excitation, which is independent of load, was 75.5 per cent. Fig. 4B is a similar set of curves for a $Y - Y$ connected bank and shows a maximum variation of 2.8 per cent on each side of the mean. The efficiency in this case was 80 per cent. In both oscillograms, prominent third and fifth harmonics appear in the current wave drawn by the transformer. The even harmonics are absent.

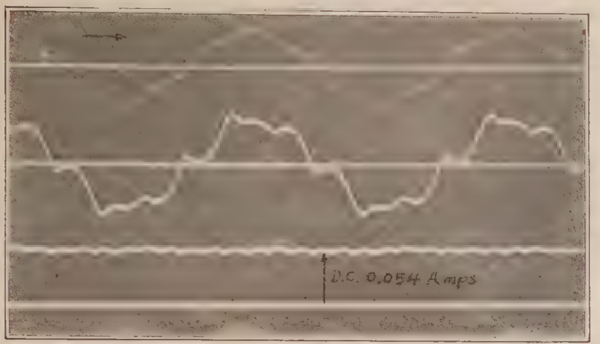

Fig. 4B—Generator Neutral Connected to Transformer Neutral

Upper curve—Transformer Impressed Voltage ($Y - Y$ Bank)
Middle curve—Current in transformer low side
Lower curve—D-c. in a water tube resistance

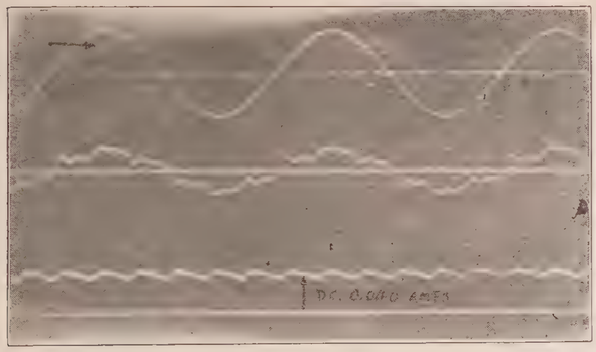

Fig. 5—Characteristics of the Rectifier on Sine Wave Voltage

Upper curve—Transformer impressed voltage ($\Delta - \Delta$ bank)
Middle curve—Transformer current in low side
Lower curve—D-c. in water tube resistance

Excitation of the compensating field amounted to 2800 ampere turns in the case of the $\Delta - \Delta$ transformer connection and 4000 ampere turns for the $Y - Y$ connection. Armature reaction in each case was 600 ampere turns. This apparently excessive compensating m. m. f. was necessary on account of the large air gap.

For comparison, Fig. 5 is presented to show the action of the rectifier with a sine wave voltage impressed. A $\Delta - \Delta$ connection was used on the transformer bank. The maximum variation of the direct current from its mean was 10.5 per cent. It will be noted also that the rectified currents produced by the flat-top wave have sharp dips occupying only about 5 per cent of the time duration of the steady portion so that even though the amplitude of the dip is four or five per cent of the total current, its net result is quite small. Sine wave impressed voltage, however, produces ripples occuping the whole time duration of the direct current.

Conclusions

There are several advantages in producing a steady high-voltage direct current without the use of a filter.

1. The expense and weakness of a high-voltage condenser are avoided. For radio work and X-Ray tube operation this is important.
2. Space requirements are reduced.
3. Power losses in the filter are avoided. (This will show up to a greater degree as the rating of the plant increases both in voltage and kilowatts).
4. Steadiness of direct current changes very little with load, whereas the filter may change its tuning under load variations.
5. The practical upper voltage limit of the rectifier is raised.
6. Undesirable even harmonics which sometimes result from polyphase rectifier loads on a power system are completely avoided.
7. The recent exhibition in England of a high-voltage d-c. generator, designed by Messrs. Highfield and Calverley, has awakened new interest in the possibilities of d-c. power transmission. The feasibility of getting a better and more easily controlled wave form for thermionic tube rectification may be another step in the solution of the d-c. transmission problem.

Results as shown leave something still to be desired in the direction of greater smoothness of d-c. voltage. Part of the unsteadiness is due to one of the transformers which was of different design, being about three per cent lower ratio and lower impedance. The ratio and impedance partly counterbalanced under load. Referring to the theoretical wave forms, Fig. 1, it will be seen that the flat-top wave has all its harmonic components, above the seventh, less than one per cent of the fundamental amplitude. If all harmonics above the seventh are missing, the total dip in the d-c. voltage wave will be only 3.5 per cent. Adding the eleventh and thirteenth harmonics reduces the dip to 2.03 per cent, at the same time shortening its time duration. Further improvement, then, is to be obtained by using lower impedance transformers and a smaller air gap in the generator.

A Study of Underground Distribution Systems
For the City of New Orleans

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Review of the Subject.—*Recent developments in a-c. low-voltage networks have aroused a condiderable amount of interest as to the application of a-c. distribution to the service requirements of business centers of large cities. Therefore, when the New Orleans Public Service Inc. was recently confronted with the necessity of rehabilitating its underground distribution system, it was decided that a thorough investigation should be made to determine the economics and advantages of various a-c. systems as compared with d-c. distribution. This paper describes the system which, as the result of the investigation, was selected to form the basis for serving the future growth of load in the underground district of New Orleans and for eventually displacing the present distribution system. An economic comparison of several types of systems which were studied is also included.*

THE underground distribution district of the City of New Orleans is shown in Fig. 1. Its boundaries include a section of the business district of the City, the estimated peak load for which in the year 1933 is approximately 14,500 kw. The present load in this area is served by a three-wire 120/240-volt Edison d-c. system which differs from the usual type of such systems in minor details only.

In connection with an extensive program of system improvement and construction which the New Orleans Public Service Inc. is now carrying out, it was recently found to be desirable to completely rehabilitate this underground distribution system. Due to important developments which have been recently made in the adaption of a-c. distribution to underground service in business districts of large ciites, it was decided that a thorough study of the economics and practicability of both present systems and new developments in underground distribution should be made before selecting the type of system which would form the basis of the proposed rehabilitation. As a result of this study, a particular type of a-c. distribution system was selected to form the basis for serving the future growth of load and for eventually displacing the present d-c. system.

FIG. 1—MAP OF THE UNDERGROUND DISTRICT OF NEW ORLEANS, SHOWING THE ESTIMATED DISTRIBUTION OF LOAD AT THE END OF A 10-YEAR PERIOD OF GROWTH

Briefly described, the system which was adopted comprises the following features:

1—Direct transmission of energy from the generating station to distribution transformers at 13,200 volts. The distribution substation will be eliminated and only one transformation will be used, the voltage of each feeder being controlled by three single-phase delta-connected automatic induction regulators located at the generating station. The distribution transformers will be single-phase units connected delta-Y, the ratio of transformation being 13,200 to 120 volts (lamp socket voltage 115). Feeders from the generating station to the distribution center will consist of three-conductor paper-insulated cable, and primary mains from the distribution center to the distribution transformers will consist of single-conductor paper-insulated cable. No sectionalizing devices or primary fuses will be used, the lead sheath of the cable being continuous from the generating station pothead to the distribution transformer case. The elimination of fuses and sectionalizing devices is made possible by use of the interconnected low-voltage network system described below.

2—The use of an interconnected network of a-c. low-voltage mains served by multiplicity of distribution transformers and by a number of 13,200-volt feeders as mentioned above. All protective devices external to the generating station will be eliminated except for reverse energy opening automatic reclosing network switches (with low-voltage fuses of large capacity to back up the operation of these switch), one switch being installed in the secondary leads of each distribution transformer bank (see Fig. 2). The automatic network switches will be similar to those now in use in a large a-c. distribution system in New York City and will provide several features of economy as well as making the

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reliability of service of the system fully equal to that of any modern d-c. system, if stand-by storage batteries be eliminated from consideration.

¶ The network switches will be controlled in the opening operation by reverse energy relays. In case of a 13,200-volt cable or transformer short circuit all transformer banks connected to the circuit which is in trouble will be disconnected from the low-voltage network by the opening of the network switches, leaving the network alive and receiving energy from the remaining 13,200-volt circuits. After the trouble is cleared, the transformer banks can be reconnected to the network merely by making the feeder alive from the generating station. Furthermore, due to the extreme sensitivity of the reverse energy relays, the opening operation can be accomplished by merely opening the generating station switch of a feeder, causing the magnetizing losses of the transformers to be supplied in a reverse direction —that is, from the network. Due to this feature, it will be possible to disconnect from the system during light load periods, the distribution transformers serving from one or more 13,200-volt feeders and to reconnect them during periods of heavy load merely by manipulating the generating station circuit breakers. This feature will be of particular value when it is desired to quickly clear a 13,200-volt circuit from the system in order to permit repairs or extensions to be made. In order to get an even distribution of load between the various distribution transformer banks, the transformers will be provided with 10-per cent internal reactance. This will result in a considerable saving in installed transformer capacity.

3—The use of one system of secondary mains for both lighting and power service, this combination being effected by the selection of a 3-phase 4-wire Y-connected system with 115-volt service (lamp socket voltage) between each live leg and neutral giving 200 volts as the delta voltage. The motor voltage in this system will not conform to the present standards but will fall within a 10-per cent variation from 220 volts. It is expected that possibly 90 per cent of all standard motors which will be operated on this system will perform in a satisfactory manner. Reduced voltage has the same effect as increasing the percentage loading of a motor or conversely decreasing the nominal load rating. Since under present conditions it is quite usual to find motors operating at loads well below the name plate rating, the reduction in voltage should have a generally beneficial effect on the system in serving to increase the power factor. Where standard motors are encountered which will not operate at the lower voltage, the situation will be remedied by the use of small auto transformers to step up the voltage to the proper amount. The above discussion, of course, applies to immediate conditions and particularly to existing a-c. motors which may be transferred from the a-c. distribution districts to the underground district, when a-c. service is established in the latter. On the other hand, wherever possible, when new equipment is involved the customers will be induced to purchase motors designed for 200-volt service. Furthermore, due to the economies which can be gained by the use of the 3-phase 4-wire system, it is to be expected that there will be some future change in motor voltage standards or in the range of variation of operating voltage within which the motors will be designed to perform satisfactorily. The change of motor design to meet the lower voltage will be a very slight one affecting, in the majority of cases, only the

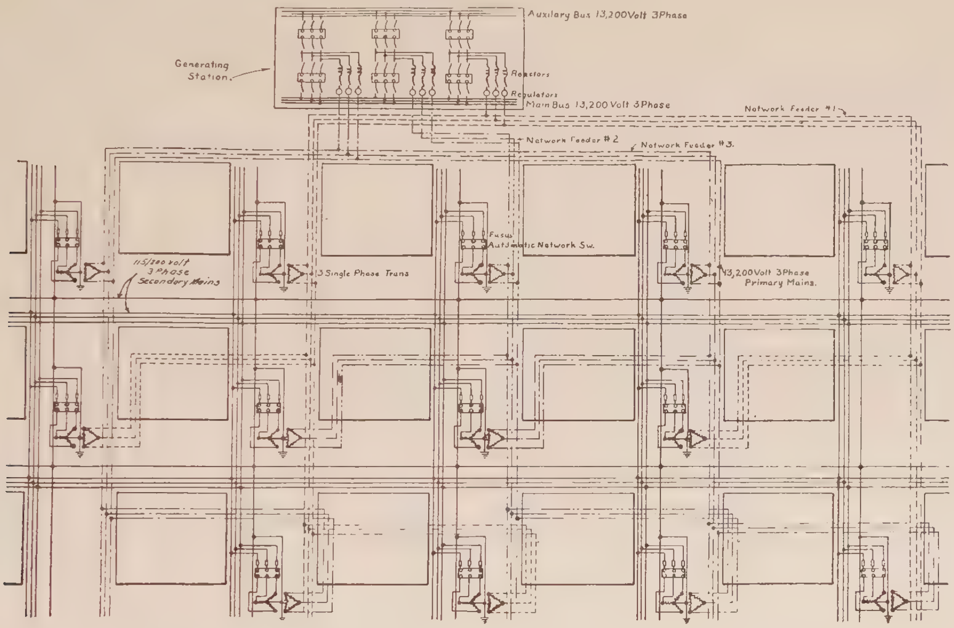

FIG. 2—ELEMENTARY DIAGRAM SHOWING GENERAL ARRANGEMENT OF CABLE AND APPARATUS IN THE TYPE OF DISTRIBUTION SYSTEM SELECTED FOR SERVING THE UNDERGROUND DISTRICT OF NEW ORLEANS

size of conductor and number of turns in the winding. Even under present market conditions special motors designed for the lower voltage can be obtained at very little additional cost.

No difficulty is expected from variations in the lighting voltage due to the starting current of motors, since in the interconnected network system conditions will be entirely different from those which obtain in the usual radial type of a-c. system. That is, the interconnection of the low-voltage mains to form a network will provide many paths for the current and will greatly decrease the magnitude of voltage dips caused by starting current of individual motors. Ample copper will be used in the low-voltage mains and notwithstanding the fact that the distribution transformers will have 10 per cent internal reactance, the stiffness of the system as regards voltage fluctuations will compare favorably with that of a d-c. system of equivalent capacity.

The change from d-c. to a-c. service in the underground district will be a very gradual process extending over a period of possibly some 30 years, the present d-c. system in the meantime being completely paralleled by the new a-c. system within the next three or four years, so that it will be possible to change over individual services at any point in the district when occasion warrants, the changes (aside from replacement of customers' equipment and in some cases changes in wiring) being merely a matter of cutting and splicing the service cables and changing the meter. The time allowed for complete elimination of the d-c. system should be sufficient to provide for 100 per cent depreciation of existing d-c. equipment, this equipment being eliminated as it becomes obsolete or unfit for service. A certain amount of changeover of customers' equipment will, of course, have to be taken care of as occasion demands. However, new d-c. equipment will be prevented insofar as possible from getting into the district.

With the advent of a-c. elevators of the unit control type and also certain successful designs of elevators involving direct application of alternating current to the elevator motor, the chief objection to a-c. service in metropolitan centers from the standpoint of utilization equipment has been eliminated, and it is confidently expected that customers will look with entire approval upon the new system.

Reliability of Service

The keynote of the New Orleans a-c. network system is simplicity. The low-voltage mains will be spliced into a solid network, no junction boxes or sectionalizing fuses being used, and dependance being placed on the ability of the system to burn off any short circuits which may occur on the low-voltage mains. This is in accordance with the standard practise in certain large d-c. systems, except for the elimination of junction boxes. The system will be designed to come within the limits which recent experiments have established as necessary to insure the burning off of any short circuits which may occur on the secondary mains. Primary short circuits will, of course, be cleared from the system by the network switches and station circuit breakers. The fact that a multiplicity of apparatus, such as substation rotating apparatus, transformers, numerous circuit breakers, etc., will be avoided, should greatly reduce the number of apparatus failures and of itself constitute an element of reliability. Furthermore, in considering the network switches themselves in connection with the reliability of the system as a whole, particular note should be made of the fact that full reliance will be placed in no one switch. The failure of one or more switches to function will not necessarily mean service interruption, for in this case the secondary fuses backing up a faulty switch or switches will be blown and will eliminate the faulty apparatus from the system. Sufficient primary feeder and transformer capacity will be provided to carry the maximum yearly load with one feeder and its corresponding transformers out of service and without loading any unit appreciably above normal capacity under this condition. This is, of course, in accordance with conservative design and corresponds with the usual practise as to transmission feeders under conditions where continuity of service is of primary importance.

In view of the above considerations and of the experience that has already been gained by other companies in the application of the a-c. network principle, the designers of this system feel confident that the reliability of service will be entirely adequate for any requirements which may be placed upon it.

Comparative Costs and Efficiencies

Aside from reliability of service, the chief reasons for selecting the system described above will be apparent by referring to Tables I, II, III and IV showing the costs and efficiencies for the five types of distribution systems which were considered for use in New Orleans. These systems may be very briefly described as follows:

(1) 13,200-volt primary with network secondary.

This is the system which was described above and no additional details need be given.

(2) 13,200-volt radial.

This system differs from the above in that each transformer bank would feed an isolated section of secondary mains, no attempt being made to operate the transformers in parallel.

(3) 4000-volt primary with network secondary.

This system is similar to the system described above, except that the distribution would be at 4,000 volts instead of 13,200 volts, necessitating in this case the usual transformer substation.

(4) 4000-volt radial.

This is the familiar 4000-volt, 4-wire grounded neutral system, each 4000-volt feeder serving an individual district and each individual transformer bank serving an isolated section of secondary mains.

TABLE I

SUMMARY OF TOTAL ANNUAL CHARGES

	Network 13,200 Volts	Radial 13,200 Volts	Network 4000 Volts	Radial 4000 Volts	Combined A-C. and D-C.
Charges on New Investment at 14 per cent	$193,000	$233,000	$277,500	$306,500	$335,300
Energy Charges for Losses	18,920	22,730	37,680	40,440	103,206
Demand Charges for Losses	32,310	27,490	61,170	52,050	123,980
Substation Operators' Salaries			11,900	11,900	Automatic
Maintenance of Network Switches	1,780		2,560		
Total Annual Charges	$246,010	$283,220	$390,810	$410,890	$562,486

TABLE II

SUMMARY OF NEW INVESTMENT FOR VARIOUS PARTS OF THE SYSTEM

	Network 13,200 Volts	Radial 13,200 Volts	Network 4000 Volts	Radial 4000 Volts	Combined A-C. and D-C.
Secondary Mains and Ducts	$596,000	$596,000	$492,000	$492,000	$262,000
Secondary Junction Boxes		24,000		32,100	102,300
Network Switches	48,000		64,200		
Distribution Transformers	206,500	266,000	215,500	287,000	35,800
Transformer Manholes	67,200	112,700	87,300	142,400	36,500
Transformer Vaults	22,900	22,900	15,200	15,200	
Primary Switches and Fuses		172,500		85,800	18,400
Primary Automatic					
Double Throw Switches		12,700		6,300	
Distribution Primary Cables	117,600	139,000	112,300	133,000	30,800
Distribution Feeders	180,000	180,000	105,400	105,400	767,000
Regulators	116,300	116,300	87,600	87,600	5,600
Space for Regulators in Generating Station	24,200	24,200			
Substation exclusive of Regulators			645,000	645,000	1,003,000
Transmission Lines and Ducts			157,800	157,800	133,400
Total New Investment	$1,378,700	$1,666,300	$1,982,300	$2,189,600	$2,394,800

TABLE III

ANNUAL ENERGY LOSSES IN THOUSANDS OF KILOWATT-HOURS AND OVERALL EFFICIENCIES

	Network 13,200 Volts	Radial 13,200 Volts	Network 4,000 Volts	Radial 4,000 Volts	Combined A-C. and D-C.
	Multiply by 1,000 to obtain kw-hr.				
Total *M* kwh. delivered at Sec. Mains	56,300	56,300	56,300	56,300	56,300
Losses in Sec. Mains	538	354	322	233	54
Losses in Network Switches	87		114		
Losses in Distribution Transformers	1,760	2,639	1,498	2,182	188
Losses in Distribution Primary Cable	4	4	9	9	1
Losses in Distribution Feeders	429	393	341	292	1,650
Losses in Regulators	346	403	263	309	21
Losses in Substation exclusive of Regulators			3,290	3,290	14,850
Losses in Transmission Lines			451	451	400
Total kwh. delivered at Generating Station	59,464	60,093	62,588	63,046	73,464
Overall (Annual) Efficiency	94.7	93.7	90.0	89.3	76.7

TABLE IV

LOSSES IN KILOWATTS AND EFFICIENCIES AT SYSTEM PEAK LOAD

	Network 13,200 Volts	Radial 13,200 Volts	Network 4,000 Volts	Radial 4,000 Volts	Combined A-C. and D-C.
Kw. Load at Sec. Mains	14,625	14,625	14,625	14,625	14,625
Losses in Sec. Mains	123	56	76	38	5
Losses in Network Switches	13		17		
Losses in Distribution Transformers	396	343	345	293	26
Losses in Distribution Primary Cable	2	2	4	4	1
Losses in Distribution Feeders	178	178	141	141	750
Losses in Regulators	86	86	59	59	4
Losses in Substations exclusive of Regulators			483	483	2,740
Losses in Transmission Lines			205	205	182
Kw. Load at Generating Station	15,423	15,290	15,955	15,848	18,333
Efficiency at System Peak Load	94.8	95.6	91.7	92.2	79.7

(5) Combined d-c. and a-c.

The figures shown for this system are based on retaining the present d-c. system in the most heavily loaded section of the underground district and changing the more lightly loaded sections to the 4000-volt radial system.

The figures for all of the a-c. systems are based on 3-phase, 4-wire, 115/200-volt service, and the calculations

were all worked out in considerable detail, the economics of transformer spacing, etc., being determined for each separate system before the final calculations were made. The figures apply to that portion of the distribution system between the generating station circuit breakers and the customers' service laterals. It will be noted that the annual charges, as well as the necessary new investment for the network 13,200-volt system will be just slightly more than half the corresponding amounts for the combined d-c. and a-c. system; that is, slightly more than half what it would cost to serve the growth of load if the present d-c. system were retained in the main business district. The costs of the other systems are intermediate between these two extremes. It will also be noted that the efficiencies of any one of the a-c. systems would be far superior to those of the combined d-c. and a-c. system. The figures are all based upon a 10-year period of growth, the annual charges and the efficiencies being those which would exist at the end of this period.

Physical Characteristics of the System

The following details of cable sizes, transformer capacities, etc., of the adopted system will be included here as a matter of interest. The three conductor feeders from the generating station to the center of distribution will be paper-insulated lead covered, the conductor size being 4/0 *A W G*. Induction regulators in the generating station will be single-phase 13,200-volt primary, designed for 10 per cent buck or boost with an ampere capacity of 150 amperes for each leg of the feeder. Primary mains will be single-conductor paper-insulated lead covered cable No. 2/0 *A W G* and No. 3 *A W G*. Secondary mains in the main business district will be single-conductor, 500,000-cm. rubber-insulated cable, and in the outlying sections will be No. 4/0 *A W G*, single-conductor rubber-insulated cable. The three live conductors will be installed in one duct wherever possible. The neutral conductor will be of the same size as the live conductors where underground d-c. service does not exist. It will, however, have only a weatherproof covering. Wherever possible, the existing d-c. neutral will be used also for the new system. Distribution transformers will be designed for 13,200 volts primary and 120 volts secondary, the capacities being 25, 50 or 100 kv-a. for each single-phase unit, three units of the same size being required for a bank. These transformers will be of the subway type and will have 10 per cent internal reactance. Network switches will have ampere capacities corresponding to those of the transformer banks and will be totally enclosed in submergible cases. The low-voltage fuses will be contained in the same case as the network switch.

Conclusion

Data have been presented showing that considerable saving can be effected both in investment and in operating charges during a 10-year period of growth by introducing a special type of a-c. system, paralleling the present d-c. system in the underground district of a particular large city. The a-c. system selected in this case will consist of 13,200-volt feeders, feeding directly into distribution transformers, which in turn will serve an interconnected low-voltage 3-phase 4-wire system through automatic network switches. This system is one of several which were investigated and it is the most economical, under the particular conditions encountered of all those considered.

The practicability of the proposed system has been thoroughly investigated, and while certain difficulties in establishing such a system are recognized, and experience may bring about some modifications of details, methods of overcoming the outstanding difficulties are available in all cases.

Special consideration has been given to reliability of service, and the selected system contains features which provide a high degree of reliability, comparable with that of the best of modern d-c. systems, if stand-by storage battery equipment be eliminated from consideration.

EDDY CURRENT LOSSES IN TWISTED CONDUCTORS

By Lionel Fleischmann

The losses due to unequal distribution of alternating current in copper conductors in half-open slots have been treated by numerous authors. The method given here does not disclose any new results but it shows an elementary way by which to arrive at an understanding of these not always simple phenomena.

Although this method lends itself to a treatment of all kinds of twisted conductors, we shall here only consider the so-called half twist bar. The conductor is built up of a number of strands so transposed that the top strand in the first half of the slot length will be on the bottom for the second half slot length. The general arrangement of the strands is shown in Fig. 1. No account is taken of the cross-over zone in these calculations.

We consider the conductor composed of $2\,n$ strands of infinitely thin conductors. The circulating current between two adjacent strands m and $m-1$, if r is the resistance of a single strand, will be determined by the equation

$$(i_{m-1} - i_m)\,\gamma + \left\{ \frac{d\,\phi}{d\,t}(m-1, m) - \frac{d\,\phi}{d\,t}(m, m-1) \right\} 10^{-8} = 0$$

or

$$(i_{m-1} - i_m)\,\gamma + \frac{d}{d\,t}\left\{ \Phi_{m-1,\,m} - \Phi_{m,\,m-1} \right\} 10^{-8} = 0$$

$\Phi\,(m-1, m)$ designates the flux between strands $m-1$ and m in the left hand side of the bar while

$\Phi\,(m, m-1)$ is the flux passing between the strands m, and $m-1$ in the right hand side of the bar. The sign of the e. m. f. in this part must be the reverse of that in the other part as the fluxes are taken in the same direction, but owing to the crossing of the strands in the middle of the conductor, the e. m. f. in this part of the circuit is counteracting that induced in the first part. The fluxes may be found by the following reasoning. Calling the total height H, the length of the slot L and the width W, the flux induced in the left hand side the equations is then

$$(i_{m-1} - i_m) - \frac{d}{d\,t}\left\{ \frac{\lambda}{\gamma} \sum_{m}^{n} i_k \right\} = 0$$

For the n conductors we obtain $n-1$ similar equations which together with the equation

$$2 \sum_{0}^{n} i_k = I$$

(where I is the total current and sine function of time),

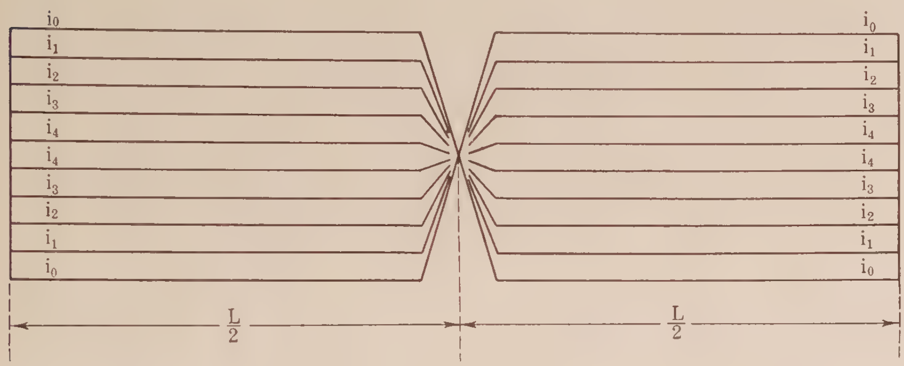

FIG. 1

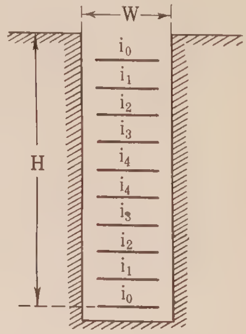

FIG. 2

between strands $m-1$ and m will be (m being smaller than n)

$$\frac{4\,\pi}{10}\,\frac{H}{2\,n}\,\frac{L}{2\,W} \sum_{0}^{m-1} i_k$$

where i_k is the general term for the current in any strand; the flux induced for the other side will be

$$\frac{4\,\pi}{10}\,\frac{H}{2\,n}\,\frac{L}{2\,W}\left\{ \sum_{0}^{m-1} i_k + \sum_{m}^{n} i_k + \sum_{n}^{m} i_k \right\}$$

gives us the necessary n equations to solve the problem. We shall however not do this, but we shall correlate this system of equations to that of the parallel stranded conductor of which by aid of the formula given by Field and others we are able to calculate the losses. Designating the currents in the strands by j with the same subscripts used above, the equation for the corresponding strand in a conductor of one half the height is

$$(j_m - j_{m-1})\,\gamma$$

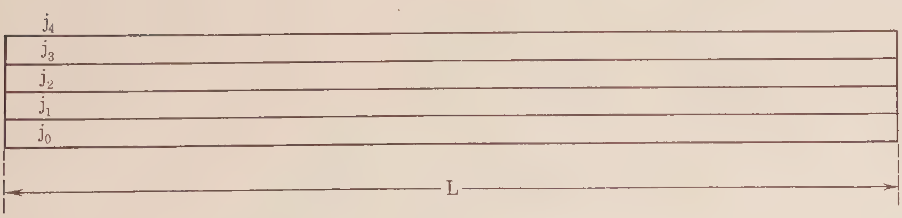

FIG. 3

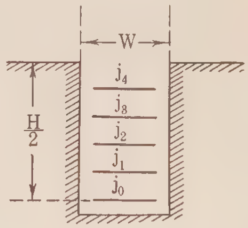

FIG. 4

As this flux must be subtracted from the former to get the total induced e. m. f. in the circuit, the final equation is as follows:

$$(i_{m-1} - i_m)\,\gamma$$

$$-\frac{d}{d\,t}\left\{ \frac{4\,\pi}{10}\,\frac{H}{2\,n}\,\frac{L}{W} \sum_{m}^{n} i_k \right\} 10^{-8} = 0$$

Substituting $\lambda = \left\{ \frac{4\,\pi}{10}\,\frac{H}{2\,n}\,\frac{L}{W} \right\} 10^{-8}$

$$-\frac{d}{d\,t}\left\{ \frac{4\,\pi\,H\,L}{10\,(2\,n-1)} \sum_{0}^{m-1} j_k \right\} 10^{-8} = 0$$

The total current is, assuming the same average current density as with the half twist conductor,

$$\sum_{0}^{n} j_k = \frac{I}{2}$$

As i_n enters into all equations of the first system and j_0 in all equations of the second system, i_n will corre-

spond to j_0. In order to find the general law let us consider the special case of $2n = 8$.

First System

$$\sum i_k = \frac{I}{2}$$

$$i_2 - i_3 - \frac{d}{dt}\frac{\lambda}{\gamma} i_3 = 0$$

$$i_1 - i_2 - \frac{d}{dt}\frac{\lambda}{\gamma}(i_2 + i_3) = 0$$

$$i_0 - i_1 - \frac{d}{dt}\frac{\lambda}{\gamma}(i_1 + i_2 + i_3) = 0$$

Second System

$$\sum j_k = \frac{I}{2}$$

$$j_1 - j_0 - \frac{\lambda}{\gamma}\frac{d}{dt} j_0 = 0$$

$$j_2 - j_1 - \frac{\lambda}{\gamma}\frac{d}{dt}(j_0 + j_1) = 0$$

$$j_3 - j_2 - \frac{\lambda}{\gamma}\frac{d}{dt}(j_0 + j_1 + j_2) = 0$$

From this we deduce

$$i_3 = j_0$$
$$i_2 = j_1$$
$$i_1 = j_2$$
$$i_0 = j_3$$

or current i_k in the first system is equal to current j_{n-k} in the second system, as they cannot differ by a constant value. Therefore the losses in the twisted conductor of height H will be double those of a parallel strand conductor of height $\frac{H}{2}$, if each conductor has the same nominal current density.

Discussion at Midwinter Convention

OVERDAMPED CONDENSER OSCILLATIONS[1]

(STEINMETZ)

PHILADELPHIA, PA., February 5, 1924

Prof. V. Karapetoff: I should like to draw your attention to a simple mechanical model which is represented mathematically by the same differential equations as the electric circuit discussed in the paper. Think of a horizontal helical spring attached at one end to an immovable wall and at the other end to a mass supported on frictionless rollers. Let there also be a tank with viscous fluid, and let a vane attached to the mass be immersed in it. Without this viscous fluid we would have a simple oscillating system; by starting it from a position which is not one of equilibrium, and letting it go, we would produce oscillations which theoretically would go on forever. By adding a vane and a viscous liquid we get damped oscillations; mathematical equations for this system are exactly the same as the equations for a circuit containing R, L and C, but no leakage.

Now, to imitate the circuit which Dr. Steinmetz considers, we shall remove the solid wall and replace it by a yielding reaction which we can imagine to be a cylinder, with a piston, a piston rod to which the above spring is attached, and a by-pass between the two sides of the piston. Let the cylinder be filled with a viscous fluid. The liquid circulating through the by-pass will constitute a yielding support for the spring.

If the support is immovable, there is only one differential equation, but by adding this yielding support, you add a second equation, namely, that the velocity of motion of the mass consists of the velocity due to the compression of the spring plus that due to the conductance of the by-pass. This gives Steinmetz' second equation. This model enables us to study and to visualize, so to say, this electric circuit. If you cannot see from the equations why the circuit becomes more oscillatory by the addition of that by-pass, your engineering intuition might tell you that this is so from an inspection of the model.

If for purely qualitative analysis, this model is too complicated, you can use a simple pendulum. Suspend a simple pendulum in a viscous fluid and you get the first equation in the paper. Add a yielding support, any kind of imperfect support, and you get the second equation of the paper. To record the phenomenon under discussion put a soft brush on the pendulum, dip it in ink, and let the brush make a record on a piece of paper moving at a uniform speed past the pendulum.

1. A. I. E. E. JOURNAL, Vol. XLIII, May, p. 424.

FREE CONVECTION OF HEAT IN GASES AND LIQUIDS-II[1] (RICE)

PHILADELPHIA, PA., February 5, 1924

V. M. Montsinger: About ten years ago or something over, Dr. Langmuir published his first paper on the film theory, in which he showed the remarkable agreement between the test results and calculations, at high temperatures, principally from 100 up to 1000 degrees. I could never get satisfactory results at temperatures below 100 degrees, which is a very important field for electric apparatus, especially transformers, generators and motors, and in fact, Dr. Langmuir himself agreed with me that the film theory did not check exactly at these low temperatures, and there was some factor that was not exactly known. Now, fortunately, Mr. Rice has shown us the method to use and has introduced a factor that takes care of the discrepancies.

For the first time I feel that we really understand the phenomena of free convection in air for both small and large temperature differences. The solution of this has been made possible principally by the use of the apparently little used and little understood "Method of Dimensions."

It will be worth while to say a few words as to what the Method of Dimensions is and how it is used. Method of dimensions simply means that each factor such as air density, viscosity, conductivity, temperature rise, etc., that affects the rate of transfer of heat from a heated surface to the air is expressed in terms of the dimensions of the body like L for the length and L^3 for the volume or T for time or θ for temperature rise. For instance, density is represented by mass M, divided by the volume L^3. Conductivity is represented by the heat, H, divided by the factors of length, L, time T, and temperature drop θ. In Mr. Rice's equation (1), each factor to start out with has its particular exponent of say, x, y, z or n, etc. In equation (2) the dimensional equivalents are substituted for the

1. A. I. E. E. JOURNAL, Vol. XLII, December, p. 1288.

factors themselves such as density, viscosity, etc., but the equation retains its original exponents. By equating the value of the exponents for length, mass, time, heat, and temperature and solving the simultaneous equations any exponent may be expressed in terms of some particular one, like, say n or m.

Having obtained the relationship between the letters representing the exponents, the exponents of each factor in equation (1) can now be expressed in the same terms as for instance; n or $\frac{3\,n}{2}$. It happens however, that all but one can be expressed in terms of n, the remaining one being m.

The numerical value for anyone of these exponents must, of course, be obtained by experimental test. But after we have determined the value of, say n, for one factor like the variation in loss with air density, we also have the solution for the correct exponents for all the other factors because they are also expressed in terms of n. In other words if we find that loss is proportional to the square root of the air density in which case n equals ½, we know how the loss is affected by a change in each of the other factors such as viscosity, temperature rise, or dimensions of the object. Thus by taking advantage of what the method of dimensions can tell us we greatly reduce the number of experiments which have to be tried in order to determine the law for the system of similar bodies under consideration. This is where the Method of Dimensions comes in and serves as a very useful tool.

In addition to the value of the correct exponent for temperature rise, that is, whether the loss is proportional to temperature rise raised to the 5/4 or some other power, there has been a considerable difference of opinion as to the correct value of the exponent for air density. In other words, does the loss vary as the density raised to the ½ or 2/3 power or some other power? The value of exponential values claimed by different investigators has been from about 2/5 to 2/3 or ¾. I have never made any accurate laboratory tests to determine this but from my experience in testing transformer tanks having different shapes of surfaces at different altitudes I have found that the value of ½ checks best the observed values.

In regard to the convection loss varying as the temperature rise raised to the 5/4 power I have been quite certain for several years that this exponential value is about correct.

As mentioned before since the Method of Dimensions shows a definite relationship between the exponents for the different factors if we are certain of one we know also what the others should be. I note with a great deal of interest that according to the Method of Dimensions if the 5/4 power is correct exponent for temperature rise it requires that the exponent must be ½ for air density. I believe therefore that Mr. Rice has proven beyond a reasonable doubt that loss by free convection in air should vary as the square root of the barometric pressure especially for large vertical surfaces.

As to the effect of height of plane on loss by convection my experience has been that for heights over three or four feet the affect of height is very small. I had occasion some two or three years ago to test the efficiency of different shapes of corrugations having a uniform (unity) vertical surface temperature gradient. These tests showed that the convection loss for a height of 72 in. was only about 3 per cent less than the loss for the same corrugations 36 in. in height. In other words the convection decreased roughly 1 per cent for each foot increase in height over 3 ft. In fact in practise I have never made any decrease in loss per unit area of corrugations (where most of the heat is carried away by convection) for heights over three or four feet.

Griffeths and Davis referred to in the paper found that the loss by convection per unit area was approximately the same for heights ranging from about 23 in. to 104 in. although they found that the value of the exponent increased slightly over 5/4 for the higher surfaces. However for heights under about one foot they found that height had a very decided effect on the loss by convection. This is as it should be according to the factor H ¼ in the method of dimensions.

C. W. Rice: There is just one thing which I would like to emphasize in closing the discussion and that is the need of more data on the free convection from various families of similar figures such as spheres, short cylinders, etc.

THE MAGNETIC PROPERTIES OF THE TERNARY ALLOYS, Fe-Si-C (YENSEN)

PHILADELPHIA, PA., February 5, 1924

Thomas Spooner: In conversation recently with an engineer of a large public service company, I asked what the value would be to his company of reduced core losses in transformers. Without any hesitation, showing that he had previously given this matter careful consideration, he told me that core losses were worth to his company approximately $800 per kilowatt for distributing transformers and from $300 to $400 for power transformers.

Taking these figures and applying them to certain standard distributing transformers, by simple calculation, I found that for a 5 kv-a. transformer, a reduction of twenty per cent in core loss would make it possible for a customer to pay approximately eight cents a pound more for the core material. For a 200-kv-a. transformer, this figure was approximately twenty cents a pound. This is on a basis of no re-design of the transformers.

The improved electrical sheet, made by the methods outlined by Mr. Yensen, would of course cost considerably more to manufacture. I think though there is no question but what progressive customers who know how to get the most for a dollar, would be very willing to pay the increased cost of this material in order to obtain transformers of improved quality.

M. G. Newman: The most interesting and vital point that is brought out is the effect of carbon. If there is carbon even in very small quantities, as Mr. Yensen points out, it is very detrimental, and silicon, while really it does not affect the magnetic properties of the material itself, does do something to the carbon there.

Most of our magnetic sheet steel, however, is used in alternating-current machinery in very thin laminations, and silicon does help out there, of course, in increasing the electrical resistance and decreasing the eddy-current losses. That brings up one question I would like to ask Mr. Yensen. Will it be possible to roll this material into sheets and obtain the same curves he has presented to us, and if not, what will be the effect on the material when rolled into sheets where it is finally used?

J. B. Whitehead: We know that the basic laws of the electrostatic field, and those of the magnetic field all take their beginnings from very much the same character of fundamental physical principles; but we also know that the parallel which exists between electrostatic phenomena and magnetic phenomena cannot be carried very far.

The increase in electrostatic flux density which follows the introduction of a dielectric, is called "electrostatic induction" just as the increase in flux density in magnetic material following the introduction of iron is called "magnetic induction." However our parallel cannot be carried any further. We find the dielectric constant of the material is really a constant so far as we can determine all the way up to breakdown, whereas the permeability of magnetic materials as we know departs very markedly indeed from a constant value, very early in the increase of magnetic induction. So while we have always hoped that some day we would be able to tie together in some fundamental way the behavior of magnetic materials, and the behavior of dielectric materials, and in a way which could be traced back to our fundamental relations, where they are of the same character, we have never yet I think come so near to it,

1. A. I. E. E. JOURNAL, Vol. XLIII, May 1924, p. 455.

as we seem to be doing in some of the results that are obtained by Mr. Yensen. I refer particularly to the initial portions of these curves in which he speaks of the carbon as being in solution with the iron, and his showing there that the losses that occur are the direct result of the combination, in the form of solution of these two materials.

Now, wherein does the parallel lie? I think it lies in this: That so far as the losses in dielectric are concerned, about the only safe starting point we have is the suggestion of Maxwell, that dielectric losses are really to be attributed to the mixtures of different materials. We are still uncertain as to whether we can say absolutely that dielectric absorption is present at all in pure materials, but the suggestion of Maxwell, and those who have followed after him in the study of dielectric hysteresis, is that the loss itself is largely due to the mixture of two different materials. Mr. Yensen now shows that magnetic hysteresis loss is also due to a combination of materials.

T. D. Yensen: In regard to the question raised by the first speaker about phosphorous: Of course, this curve does not mean that if you start with the material of zero hysteresis loss, that is, with all the impurities eliminated and of infinite grain size, and then add phosphorous to it, that a material of negative hysteresis loss will result. It means that in connection with other impurities and in connection with material having a finite grain size, phosphorous seems to be beneficial to the magnetic properties of four per cent silicon steel. As a matter of fact, this effect is so very small anyhow, as compared with the effect of sulphur and carbon, that it does not make very much difference whether the curve is drawn as shown or horizontal. In other words, the effect of phosphorous on *Fe-Si* alloys can be regarded as negligible.

In regard to Mr. Newman's question as to whether these same relationships hold for sheets, I can say that as far as we know they do. There is one factor that we have not yet considered, that we have not studied systematically, and that is, the effect of oxidation. In heavy materials, in big samples, the effect of oxidation is not very great, but the thinner the material becomes, the greater will be the effect of surface oxidation, and great precautions must be taken to prevent excessive oxidation when this material is rolled into sheets.

As far as actual results are concerned, I might add this: by taking special precautions we have been able to get material in sheet form with a loss considerably less than one watt per kilogram for 10,000 gausses at sixty cycles. Those of you who are familiar with magnetic materials will realize that this is quite an advance, because the ordinary materials that you have been using in transformers up to the present time have a loss of one and a half watts per kilogram or more. Better than this has been obtained during the last few years, but that is an average figure, so you will see that if you can reduce the loss to less than one watt per kilogram, you will have obtained an improvement of over fifty per cent. Mr. Spooner mentioned the fact that if we could decrease the loss by twenty per cent, we could afford to pay twenty cents a pound for the material, and by decreasing it fifty per cent, we might be able to place iron-silicon alloys in the same class as iron, nickel and other semi-precious materials.

Haakon Styri (by letter): I find two points which would be of great interest to have explained; one is the probability of having the second term of the hysteresis loss corresponding to free cementite continued to higher carbon contents when the steel has been prepared in such manner as to produce granular pearlite instead of lamellar pearlite. Such condition of the steel can readily be obtained by quenching at high temperature, followed by proper drawing.

The other question which to me particularly is of great interest, but which would probably mean a large amount of work, is to find by the same kind of magnetic analysis, how the saturation point for solid solution of carbon varies with temperature. I would believe that by increasing temperatures the amount of carbon going into solution, should increase.

If variation of magnetic properties with temperature could be determined, this would certainly throw some light on whether it was proper to consider the carbon in solution either as cementite or as free carbon, and whether the influence of carbon on the magnetic properties might be due to dissociated ionized carbon. It can certainly not be possible that carbon could have such influence on the magnetic properties if only mechanically dissolved.

T. D. Yensen (by letter): Replying to Dr. Styri, my conclusion in regard to the slopes of the hysteresis loss vs. carbon for 0% Si between A and C and C and D (Fig. 15) was that the hysteresis loss in both cases is due to the inherent hysteresis loss of Fe_3C, but that the actual flux passing through the Fe_3C is much greater in the case of pearlite (for $C > 0.1\%$) than in the case of free Fe_3C $(0.01 < C < 0.1)$. It is my opinion, therefore, that the actual hysteresis loss will, in any given case, depend upon the relative distribution of Fe_3C and ferrite. If granular pearlite gives a distribution whereby the magnetic flux will tend to avoid the Fe_3C more than in the case of lamellar pearlite, then the slope of the $C — D$ part of the curve should become less. However, as the concentration of Fe_3C becomes greater I should venture to say that the slope should increase and approach the slope $C — D$ shown in Fig. 15. To test this out experimentally would be somewhat difficult, as we should have to introduce another variable due to the heat-treatment, apart from the effect on the Fe_3C, and this might screen the effect due to the difference between granular and lamellar pearlite.

The second question brought out by Dr. Styri, namely; whether the saturation point for carbon in solution (0.006 — 0.008 for 20 deg. cent.) increases with increase in temperature, is a very interesting one, and I hope to be able to investigate this point at some future date. It would be natural to assume that the solubility should increase with the temperature; on the other hand, we know that Fe_3C all goes into solution at the A_1 transformation point which may or may not harmonize with a gradually rising solubility curve between 20 deg. and the A_1 point.

Whether carbon in solution (martensitic) exists as Fe_3C or as free carbon apparently is a question not yet answered to everybody's satisfaction. Reference might be made to arguments of Jeffries (*Chem. & Met. Eng.*, Vol. 24, p. 1057, 1921 and Vol. 26, p. 250, 1922 which are in favor of the free carbon hypothesis. Westgren at first opposed this view, but later admitted that Jeffries' conclusion probably is correct (*Jour. Iron & Steel Inst.*, Vol. 95, p. 241, 1922, No. 1.)

The tremendous effect of carbon in solution is, to my mind readily explained either by the substitution theory, whereby one atom of a foreign element is capable of replacing one of the solvent atoms and thereby distorting the entire original space lattice, or on the assumption that the carbon atoms enter the interstitial spaces between the Fe and Si atoms. (See Walter Rosenhain: Solid Solutions, A. I. M. E. preprint No. 1250 N, June 1923). Dr. Styri has just called my attention to a paper by Dr. Westgren (*Jernkontorets Annaler* 1923) where he proves that the latter view is the correct one.

E. Gumlich (by letter): I was pleased to note that Mr. Yensen, by means of much better basic materials, perfected analytical methods and plentiful support, has succeeded in going much further than I could in my own investigations. Twenty years ago when most of my test pieces were prepared, the standards in regard to purity of iron were much lower than now, when we have available for the preparation of alloys an almost pure base, *viz.* electrolytic iron; it is therefore the more gratifying that our results, at least in general, coincide. For instance, the fact, observed by Mr. Yensen, that in the region of C-content between 0.006 per cent and 0.09 per cent, free iron carbide, Fe_3C, affects the magnetic properties and electrical resistance much less than Fe_3C in solution or in the form of pearlite. This is in agreement with the observation made by me in many cases, that the effect of carbon on the electrical resistance as well

as the coercive force and the saturation value is much less pronounced for alloys with C-content in excess of 0.9 to 1 per cent, than for alloys with less than this amount of carbon, whether the material is slowly cooled or quenched; in other words, whether the carbide grains, precipitated in hypereutectoid alloys, is embedded in a pearlitic or a martensitic base.

The corresponding diagrams can be found in full only in my complete article in Wissenschaftlichen Albandlungen der Ph. Tech Reichsanstalt, Vol. IV, Part 3, and only partially in an abstract published in E. T. Z., 1919.

I consider very important the fact, found by Mr. Yensen and perfectly well established, that carbon to the extent of at least 0.006 per cent, remains in solution even after very slow cooling and, therefore, has a correspondingly large effect. This phenomenon was naturally overlooked by me, because of my much less pure material and less exact method of C determination. At that time these factors were of no practical importance, while today, when the manufacture of entirely pure iron and the investigation of its magnetic and electric properties is our goal, these factors come to assume greater and greater importance. (In Fig. 14, there seems to be a mistake in that the C-content plotted as abscissas only refers to the lower, not to the upper curve; for the latter the abscissa values should be multiplied by about 20; also in the table entitled "Form of Precipitated Carbon" in the section for 4 per cent Si there seems to be a misprint; it should be"—4000 P" instead of "—400 P.")

Of particular interest to me was Mr. Yensen's demonstration in regard to the relationship between the grain size and the magnetic properties, which has often been mentioned, but never definitely established.

On the other hand, according to our measurements I cannot consider the data on saturation values for pure iron to be correct; using field intensities at our disposal, (6-7000 gauss), we have always obtained by various methods $4 \pi I = 21{,}600$, while the values given in the paper are 23,000 and over. We cannot believe that the comparatively small amount of impurities in our electrolytic iron can noticeably affect the saturation value. It is, therefore, probable that the method used in obtaining the saturation value (not described in the paper) may be responsible for the discrepancy.

Finally, quoting the motto "Qui tacet, consentire videtur," I should like to correct one point in the article, which concerns me personally. In the first paragraph of the introduction it is stated that the discovery of the advantage of silicon steel as compared with ordinary iron was made by Sir Hadfield. Strictly speaking this is not incorrect, since Messrs. Barrett, Brown and Hadfield found that magnetic properties of many Si and Al alloys were better than their basic materials (their article in the *Sc. Trans.* Roy Dublin Soc. VII, 1900); but absolute values for these new alloys were in no way exceptional and did not reach those for rolled iron or good ingot iron. This is clear from the fact that the first sample of Hadfield's Si-iron, which was sent by Fr. Krupp Co. to the Reichsanstalt for magnetic test, had a coercive force of 1.45 and a hysteresis loss of 12,300; at the same time the best grades of iron at that time had a coercive force of between 0.6 and 1 gauss and a hysteresis loss of between 4900 and 10,000, and the director of the Krupp Co. told me personally, that his factory had no interest in this new material at all. This interest was only aroused after it had occurred to me to utilize the high resistivity of the Si-alloys for lowering the eddy-current loss in transformer and generator sheets and after I had communicated this idea personally not only to representatives of metallurgical works and rolling mills, but also to ETZ in 1901 and 1902. Thus it happened, that at the end of 1903, when Sir Hadfield obtained his first patent in England, in Germany the manufacture of silicon sheet steel, started by my activities, was in full swing and could not be restricted by foreign patents. Whether Sir Hadfield, independently of me, came to the idea of using Si-alloys in sheet form for construction of transformers is unknown to me; anyhow, I can insist upon my priority, because the first publication by Barrett, Brown and Hadfield, by which I had been moved to my activities, gives no reference to the possibility of utilizating the high resistivity. The best proof of the correctness of my contention can be found in the fact that I could open my address in the Faraday Society of London in 1912, under the presidency of Sir Hadfield, with the following words:

"When in 1900 Messrs. Barrett, Brown and Hadfield published the results of their interesting researches on the magnetic properties and the electric resistance of iron-aluminum alloys and iron-silicon alloys, I had the idea to utilize the high specific resistance of the silicon alloys for the diminution of the eddy currents in transformer and dynamo sheet metal. The P. T. R. therefore requested some prominent German firms to produce transformer sheets out of silicon alloys, and began itself to make experiments with the new material. It resulted in the course of these experiments that more had been attained than had been expected; for not only were the eddy currents weakened in accordance with the higher specific resistance, but also the hysteresis loss was often smaller, and the permeability in low fields was higher than in the usual dynamo iron. Thus the so-called "legierte Blech" could not fail almost entirely to replace the usual material within a short time, in spite of the initial difficulty of production and of the much higher price, and German electrical engineers are much indebted to Messrs. Barrett, Brown and Hadfield for the researches which supplied the foundation for this great improvement in transformer material."

This presentation of the matter has not been corrected by Sir Hadfield; I therefore consider myself justified, in claiming the credit for being the first to have conceived and realized the idea of the application of silicon sheet steel to transformer construction.

T. D. Yensen (Communicated): Replying to Dr. Gumlich's communication, I note that he is in substantial agreement with my results in regard to the relative effect on the magnetic properties of C in the form of free Fe_3C, pearlite, and martensite. He states in his discussion that "Carbon in excess of 0.9—1.0 per cent has a much smaller effect on the electrical resistance, the coercive force, and the saturation value, than carbon contents below this value, whether the samples have been slowly cooled or quenched, *i. e.*, whether the carbide grains in these hypereutectoid alloys are embedded in a pearlitic or martensitic base." I believe this statement, to make the facts clear, should be modified by specifying that the quenching be done from a temperature sufficiently low to permit the free hypereutectoid Fe_3C to be precipitated, *i. e.*, from just above the A_1 point. If the quenching is done from a higher temperature, then obviously carbon is not precipitated at all (or only partially) but remains in solution with the corresponding effect on the physical properties. This is well illustrated in Fig. 8 of Dr. Gumlich'spaper in *ETZ* of July 3, 1919, page 328. By quenching from 900 and 1000 deg. the curves have no breaks in them at $C = 1.0$ per cent because the quenching temperatures lie above the A_3 point for all the alloys. In the case of the 1.8 per cent C alloy quenched from 900 deg. there may be a slight amount of precipitated Fe_3C but most of the carbon will remain in solution. By quenching at 800 deg. however, the carbon above about 1.2 per cent will have a chance to be precipitated as Fe_3C and he consequently obtains the break shown. It is interesting to note that the slope of the upper part of the curve ($C > 1.0$ per cent) for the 800 deg. quenching in Fig. 8 is 2.5 or identical with the slope obtained by me for the coercive force in the region $0.01 < C < 0.1$, *i.e.*, where C occurs as free Fe_3C. This consistency is most gratifying, because it shows that we have found relationship that can be depended upon. It also answers a question asked by Dr. Haakon Styri as to whether the relationship given for the region $0.01 < C < 0.1$ holds for higher C contents whenever carbon occurs as free Fe_3C. I believe the evidence given in Fig. 8 of

Dr. Gumlich's paper is sufficient to answer this in the affirmative.

Dr. Gumlich's remark in regard to Fig. 14 "that the abscissa values only hold for the lower curve, not for the upper" is correct. This is taken care of, however, in the chart as it will be noted that the upper curve is marked "Percent $C \times 10$." There is, however, a misprint in the table entitled "Form of Precipitated Carbon" in the equation for 4 per cent Si. The constant for P should be "—4000" instead of "—400." Another mistake has been made in the abscissa values for the upper part of Fig. 34. These should all be multiplied by 10; *i. e.*, they should be 0.08 to 0.56.

In regard to the saturation values, it is possible but not probable that Dr. Gumlich's value is correct. Our values were obtained by plotting $\rho = \dfrac{H}{B - H}$ vs. H for values of H up to 500 gilberts per cm. for the rod samples. As the curves were apparently straight lines for $H = 300$ to 500 we used the reciprocal of the slopes for this region as the saturation value. This is a method extensively used in the past and has been regarded as reliable. (See J. D. Ball "The Reluctivity of Silicon Steel as a Linear Function of the Magnetizing Force" *Gen. Elec. Review* 15, page 750, 1913, and "Some Notes on Magnetization Curves" *Gen. Elec. Review*, Jan. 1915) but it is possible to get values that are far off if the plotting is done carelessly. My colleague, Mr. Thomas Spooner, has recently conferred with the Bureau of Standards in Washington in regard to this matter, and finds that the saturation value for pure iron reported by the Bureau varies from 21,200 to 21,900, the most reliable value being regarded as 21,600, which checks Dr. Gumlich's value. On the other hand, Mr. Spooner has obtained actual values of $B - H$ for some of our rod samples that exceed 21,600. For example, for $H = 600$ he obtained in one case 21,890 after making all proper corrections for air space. The calculated saturation value in this case was 23,200. These results were obtained with an apparatus that checks the Bureau of Standards results within one per cent. To be doubly certain of our values, we recently sent the rods to the Bureau for checking our results for high values of H. The values obtained by the Bureau are appoximately one per cent *higher* than ours. As far as we know now, therefore, the saturation values reported in the paper are correct within a few per cent. They also check the value obtained by Dr. E. H. Williams at the Univ. of Ill. for vacuum fused electrolytic iron in the form of elipsoids (See *Gen. Elect. Rev.* 18, p. 881, Sept. 1915), the value obtained being 22,800.

As far as the values for the ring samples are concerned the writer regrets to have to report that all values of B are 3.5 per cent too high, due to an error just discovered, in the formula for calculating the cross section.

Finally, as regards the credit for the benefits that have resulted from the use of silicon steel in transformers, I think Dr. Gumlich states the matter very clearly in the introduction to his lecture before the Farraday Society in 1912 when he ends by saying:"———and the German electrical engineers are much indebted to Messrs. Barrett, Brown and Hadfield for the researches which supplied the foundation for this great improvement in transformer material." Dr. Gumlich, undoubtedly deserves great credit for having seen and understood the importance of the results obtained by his English colleagues, and for having pushed the application thereof in Germany and thereby in the rest of the world, and I think Sir Hadfield would be the last man to deny that this credit is due him. On the other hand, the world is indebted to Sir Hadfield and his colleagues for having laid down the foundation upon which the present magnificent structure has been built.

E. Gumlich (Communicated): Mr. Yensen is of course perfectly correct, when he states that the effect of free iron carbide in a base of martensite will be observed only when the quenching temperature is sufficiently low, or the carbon content sufficiently high, so that the carbon at the temperature in question will not all go into solution. While this is quite obvious to experts in this particular field, it will perhaps make things clearer if the statement is made as follows:

The effect of carbon, etc., is much less for alloys with more than 0.9 per cent—1 per cent carbon than for alloys with less than this amount, no matter whether we deal with slowly cooled alloys (in which the precipitated free carbide is embedded in a pearlitic base) or with alloys that have been quenched from a sufficiently low temperature (so that the precipitated free carbide is embedded in a martensitic base).

E. A. Smith (by letter): Within the last 10 years, many investigations have been carried on to improve alloys, for use in transformers and generators. Some of the authors covered various phases of iron and steel alloys, yet, many difficulties were still to be encountered due to the hysteresis effects and only lately the improvements have progressed fairly well. The papers that I am referring to, have been published by the German Electro-Technical Societies, The Faraday Society, Imperial Academy of Sciences of Germany and Austria, The German Iron and Steel Institute and the German Society of Engineers. I have also compared Mr. Yensen's Bulletins in 1915 and 1916 published by the University of Illinois Experiment Station, with those of the above Institutions covering iron-silicon alloys and found them all to check closely in their respective tests.

In my estimation, the present paper of Mr. Yensen seems to be fairly accurate with the magnetical properties of alloys as described and further investigations will result in many improvements to the construction of electrical apparatus.

In most metals and alloys more or less impurities exist and the grain size affects the magnetic properties and the hysteresis losses considerably, therefore, a special annealing process is being worked out at the present time by one of the manufacturing companies in Germany.

The best results can be obtained by eliminating the carbon and other impurities which appear to affect the magnetic flux much more than the grain structure. The maximum permeability of the individual alloys cannot be changed, but the resistance and reluctance can be altered, by the removal of the impurities. The numerical coefficients for the effect of the carbon on the hysteresis losses can be calculated if the structural and composition characteristics possess fixed constants or factors.

While the analysis of different alloys shows varying factors in their physical states it proves from actual conditions that many of the factors can be improved upon by the introduction of changes in their grain structures and compositions.

ALKALI VAPOR DETECTOR TUBES[1]

(Brown and Knipp)

Philadelphia, Pa., February 5, 1924

G. D. Robinson: Will the authors please state what decrease or increase of filament life is found to accompnay the use of the alkali vapor?

Referring to Mr. Knipp's discussion of Figs. 4 and 5, where he states that plate current flows with the "plate actually negative to a portion of the filament," it appears that the plate is actually negative with respect to all active parts of the filament.

Alexander Nyman: The first curve, I believe, shows the sensitivity of the detector. As a rule, it is a very difficult thing to measure the sensitivity, and I would like to know how it was measured in this case. I believe several curves show amplification constants. That is another doubtful thing in the tubes. There are two ways of measuring amplification constants; one is the amplification constant on open circuit, and the second, is with full current on the plate circuit. The easiest way to get the second is by simply having a family of plate-current and grid-voltage curves, and computing the ratio of voltages from

1. A. I. E. E. Journal, Vol. XLIII, January 1924, p. 26.

these series of curves. I would like to know which particular amplification constant is used.

With regard to the application of this tube, it seems that if it can meet all the qualifications of a detector and amplifier, it ought to make quite a good commercial product.

There is one factor that hasn't been discussed and that is the stability of this tube as an oscillator. In other words, if you have a regenerative circuit, and you are adjusting for the most sensitive conditions, unless the tube is a fairly stable oscillator, the signal will swing from non-oscillatory conditions to an oscillatory condition and distort the signal.

Hugh A. Brown: Replying to Mr. Robinson's question, no accurate data on the effect of the alloy on the life of the filament have been obtained. However, some of the tubes have been in use intermittently for nearly two years and the filament resistance has changed very little. It seems as if the presence of the alloy is not nearly so serious a factor on the filament life as is the presence of the argon and helium in the conventional gas content detector tubes. This is probably due to the fact that the alkali vapor tubes function at about 10 per cent lower filament current than do the former. It is known that potassium and sodium can form an alloy with tungsten under proper conditions, but it may be true that the alloy of these two metals is not so active. This is true in the case of glass, the separate metals will crack glass in time, but the alloy seems to have no effect.

Replying to Mr. Nyman's questions, the curve he refers to was obtained principally for the purpose of showing how critical the tubes are with varying plate voltages. The method of testing is described very briefly on page 4, of the paper. A more detailed description of the measuring apparatus can be found in the I. R. E. paper by the authors referred to on page 5. The tubes were used as "plain" detectors on a weak signal which showed 5 to 7 "times audibility" on a standard J tube used as a detector. The amplification constants were measured by an a-c. method described in Van der Bijl's book, "The Thermionic Tube," and which method the authors understand is used by the Western Electric Company in rating amplifier tubes. It is a "no load" amplification constant, but plate current flows during the measurement. The methods of measuring both "no load" and "full load" amplification constants are described in Morecroft's "Radio Communciation." The tubes are exceedingly stable oscillators, especially in the weakly excited condition and are thus excellent for "zero beat" reception.

TRANSIENT PERFORMANCE OF ELECTRIC ELEVATORS[1] (Lindquist and Yearsley)

Philadelphia, Pa., February 6, 1924

Bassett Jones: It strikes me that the paper by Messrs. Lindquist and Kearsley presents a method of solving a very large class of differential equations of almost any order and complexity involving both continuous and discontinuous functions. The method should prove of inestimable value in mathematical engineering. As the authors have shown, the method makes *the solution of even an unknown equation*, relating two or more variables, a practical possibility provided only that the actual physical relationship between these variables can be observed and graphically represented. It is not required that the mathematical expression for this relation be known, or if known in abstract form, it does not follow that the detail form of the expression is required.

The method makes it possible for the ordinary man who posesses the necessary instruments to solve real physical problems that lie beyond the reach of any purely analytical method, unless it be a most searching and complicated mathematical treatment. Unfortunately for rigorous mathematical methods, most of our real and pressing day-by-day engineering problems are of this type. If we adhere to the strict rules of the game, no solution is possible, for, as a very great man once said, "most differential equations take refuge in a definite integral and only rarely can these integrals be evaluated." By a very ingenious device, Mr. Lindquist has forced the integrals into the light of day where we can look at them, and measure them, and make an end of them. Heaviside did the same sort of thing by what he called algebraising the differentials. But if the equations are complicated, this method requires marked mathematical agility on the part of the worker.

Mr. Lindquist's method requires merely that the relation between the variables be measurable. To be of any real value, this relation must be measurable. Being measurable it can be properly represented in graphical form. The resulting mechanical integration of such unknown, and generally unknowable functions, will be quite as accurate as the basic data used.

The general method set forth in this paper opens a wide field for investigation that, mathematically speaking, up to the present time has remained either a closed book or subject only to the vaguest sort of approximations.

K. L. Hansen (by letter): Seven years ago the present writer presented a paper before the Institute, entitled "Anaylsis of Starting Characteristics of Direct-Current Motors" (Transactions A. I. E. E., Vol. XXXVI). Although the problems of acceleration discussed in that paper did not refer specifically to elevators, they were nevertheless, in many respects, similar to those discussed by Messrs. Lindquist and Yearsley.

At that time controller engineers appeared to take little interest in analysis of the transient phenomena incidental to acceleration and retardation of electric motors. The feeling seemed to be that rough approximations based on experience and cut-and-try methods were preferable to mathematical analysis. In spite of this sentiment my belief was that interest in the mathematical predetermination of these transients would increase as the requirements became more exact. The paper under discussion indicates that this belief will be justified.

To illustrate the similarity of the problems discussed in the two papers, consider the following formula developed by the authors

$$t = \frac{M\,R}{K^2} \log \epsilon \frac{F_1 \pm F - K\,I}{F_1 \pm F - K\,i}$$

F_1 and F being constants $F_1 \pm F$ may be combined into one constant, T_c, which may be positive or negative. Also writing $\frac{E}{R}$ for its equivalent I. and transforming the equation slightly we have

$$\frac{t\,K^2}{M\,R} = \log \epsilon \frac{T_c - \frac{K\,E}{R}}{T_c - K\,i}$$

Expressing this in the exponential form

$$\frac{T_c - \frac{K\,E}{R}}{T_c - K\,i} = \epsilon^{\frac{K^2 t}{MR}}$$

and solving for i

$$i = \frac{T_c}{K} + \left(\frac{E}{R} - \frac{T_c}{K} \right) \epsilon^{-\frac{K^2 t}{MR}}$$

By inserting the proper conversion multipliers this formula is readily seen to be identical with formula (10) of my paper. Incidentally it may be remarked that when publishing a formula, which has already been derived in a previous paper, it is customary to make some references to the earlier publication.

However, while the problems discussed in the two papers are similar in many respects, the authors of the paper under discussion have mainly employed a different method of obtaining

1. Published in pamphlet form.

the solutions. The authors have arrived at useful and valuable results by an ingenious application of the well known method of graphical integration, but have apparently underestimated the limitations of this method and greatly overestimated its accuracy and usefulness as compared with straight analytical methods.

The classes of differential equations, which can be integrated by quadratures, as this method is called, are very limited indeed, being those of first order and first degree, in which the variables can be separated, and those of first order from which one of the variables is explicitly absent. Very few of the differential equations met with in engineering and physics belong in this group. A little reflection will show that the limitations of the method have, in fact, prevented the authors from arriving at the complete solution of the problem they proposed to solve.

To illustrate, consider the motor and elevator having the characteristic curves shown in Fig. 7 of the paper. Assume all conditions to remain unchanged, except that a considerable inductance is inserted in the motor armature circuit. As this in no wise alters the speed-torque characteristic of the motor or the friction curve of the elevator, the same speed-time curve would be arrived at by the authors' method. The fact is that this curve may be considerably modified by an appreciable change in inductance of the main circuit. Indeed, in elevator service such inductance is sometimes employed to limit the current peaks in transition from one controller step to the next, thereby effecting smoother acceleration.

The authors' statement that "the accuracy of their method is limited only by the accuracy of the instruments used in making the speed-torque tests, and the accuracy of their observation" appears therefore to be quite inaccurate. The limitation of the method itself in not being readily extended to take into account the electro-magnetic energy stored in the system is liable to introduce errors greatly exceeding the inaccuracies of observation. The limitation of the method is again illustrated by the necessity of going to a step-by-step calculation in order to take into account the primary and secondary leakage fluxes in the problem of mutual induction.

The authors state that it is comparatively easy to apply the method they describe to determine the speed-time curves when the field currents vary, but the method of procedure in that case is not indicated. It would be of interest to see the method applied, without resorting to step-by-step calculation, to a case of continuously varying field flux, as, for example, to the system of control described by Mr. Bouton in his paper, "Variable Voltage Control Systems as Applied to Electric Elevators."

Step-by-step calculations, like the method described in the paper, are found very useful in many cases when it is impossible to deduce analytical expressions for the variables involved. However, in the vast majority of cases, analytical solutions are preferable, even when certain simplifying assumptions are made in their derivation. That the authors have greatly overestimated the errors that are likely to result from such assumptions, pertaining to these problems, will become apparent by a careful study of the calculated and test curves in Figs. 6, 7, and 8 of my paper.

When the authors state that graphic methods lead to a much clearer understanding of the reasons for transient conditions, is that statement to be interpreted to mean that they have a better understanding of these problems than one who has deduced the solutions analytically?

The expression "seriously involved" mathematics is obviously a relative term. One is likely to consider mathematics beyond one's own knowledge seriously involved. To some, the elementary calculus used in the paper undoubtedly seems like seriously involved mathematics; while to others, the application of the theory of functions to the solution of differential equations may be a simple matter. As seems to be the case with most mathematical papers, probably very few feel that the authors have used just the kind of mathematics to suit them.

E. W. Yearsley (by letter): The equation referred to by K. L. Hansen was published in the *Proceedings* of the Association of Iron and Steel Electrical Engineers in 1908 as a part of a paper on Electric Motor Drives, by E. W. Yearsley. In this paper the general treatment of systems of electric drives was outlined, both on analytical and practical bases. These equations, which are so simple as to be obvious to those who have even an elementary knowledge of physics and the calculus, were introduced in the present paper for the purpose of leading up to the graphical treatment and to call attention to the difficulties of the analytical method.

It is, of course, impossible to take into account unknown functions such, for example, as the equation of the magnetic or saturation curve in determining transients, unless either a graphical method is used or an empirical equation assumed, which approximates the function. This latter is necessary when purely analytical methods are used and the result is usually very inaccurate.

Dr. Steinmetz, in his work on Transient Phenomena, considers various magnetic problems analytically, and is compelled to resort either to the approximation of Froelich's formula or to confine himself to the basis of magnetism directly proportional to magnetizing force.

The writer has used both Froelich's and Kapp's formulas in analytical investigations of transients as long ago as 1903, but the results obtained were not sufficiently accurate. Those who have read the work of Dr. Steinmetz will appreciate the difficulties of a purely analytical treatment of magnetic transients. The purpose of the paper under discussion was to simplify the treatment of transient problems so that practical solutions could be obtained that would be of advantage in developing satisfactory apparatus for actual service.

To solve all the differential equations of electro-mechanical systems was not within our expectations, but we have obtained practical results by the methods outlined and have had no great difficulty in taking into account continually varying field fluxes.

We have been engaged in the development and investigation of transients of various sorts of electro-mechanical systems, particularly those applied to elevators, for a number of years and have investigated the operation of electric motors under many kinds of control, including the Ward-Leonard System, as described by Mr. Bouton in his paper "Variable Voltage Control Systems as Applied to Electric Motors." This system has recently come into more general favor, particularly on account of the demand for high-speed elevator equipment to be operated on alternating-current supply. It has been found comparatively easy to develop the transients of an elevator system employing this type of control.

Personally, I am interested in mathematics as a means of obtaining practical results. In this connection it does not make much difference what sort of mathematics suits various mathemeticians. The means that are simplest are most attractive to those who are developing practical apparatus.

VARIABLE VOLTAGE CONTROL SYSTEMS AS APPLIED TO ELEVATORS[1] (Bouton)

Philadelphia, Pa., February 6, 1924

K. L. Hansen: Because of the fact that the inherent speed-torque characteristic of the induction motor makes it less suitable than the direct-current motor to applications where masses of considerable inertia have to be accelerated and retarded at frequent intervals, the application of alternating-current power to certain classes of elevators presented a formidable problem. It appears that the system of control described in Mr. Bouton's interesting paper was first thought of in connection with elevators as a solution to this problem.

However, it is evident from the paper that, even when considered purely from the standpoint of control, the system must have shown some very desirable characteristics in operation, as

1. A. I. E. E. Journal, Vol. XLIII, January, p. 52.

it has frequently been extended to cases where conversion from alternating to direct current is not the object, that is to elevators on d-c. power lines.

It has long been recognized, but has of late become much more forcibly impressed upon us, that in motor applications where the starts and stops are frequent, control of acceleration by means of resistors in the armature circuit is extremely wasteful of energy, and there is consequently a general tendency to devise more economical methods of control in such cases. Application of the system described in the paper to elevators where d-c. power is available is obviously in line with the general trend towards greater economy.

Another general trend in the evolution of control apparatus is to control transient conditions, such as acceleration and retardation of motors by continuous electromagnetic changes inherent in the machines, rather than by mechanical changes, such as switching operations in the main circuits. In this respect, the system described appears to be ideal, the switching operations of the main circuit having been reduced to a minimum. The advantages of having the acceleration controlled by a continuous change in the generator field flux are also clearly set forth in the paper as being smoothness of operation and reduced maintenance cost.

However, while the system is thus seen to possess some very marked desirable features, there are some drawbacks. The total machine capacity required is more than three times that required for the elevators themselves. This, of course, refers to capacity and not to physical dimensions, as the motor-generator set is

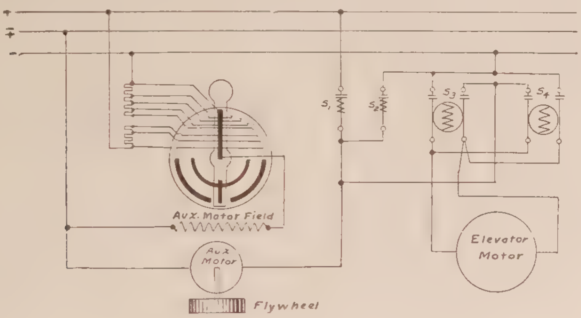

Fig. 1

undoubtedly relatively much smaller than the elevator motor, being operated at much higher speed. But even at best, the necessary additional machine capacity is undeniably a serious drawback. Furthermore, the losses in the additional machines, especially the standby losses, offset to a considerable extent the efficiency gained during acceleration and retardation.

It, therefore, becomes of interest to determine whether or not it is possible to devise a system which will materially mitigate these drawbacks and at the same time retain the most desirable features. I believe this is possible, and will briefly describe a proposed system and submit it for comments and criticism. The system is shown as applied to direct current only, the conversion being accomplished by other means when the supply is alternating current. It will first be described in combination with a three-wire supply line as the connections are then simplified somewhat. For the sake of simplicity the diagrams show only the distinguishing features, omitting those common to other systems, such as the main disconnecting switches, the circuits energizing the magnet switches, the field circuit of the main motor, etc.

Referring to Fig. 1, it will be seen that the system employs an auxiliary motor, with a flywheel to increase the inertia of its revolving parts. In the standstill position switches S_1, S_3 and S_4 are open and switch S_2 is closed. The auxiliary motor is running at normal speed between neutral and negative line. The auxiliary motor starter, being of the usual type, has been omitted from the diagram.

To start the elevator S_2 is open and S_3 or S_4 (according to whether the motion is up or down) is closed, thus inserting the main motor in series with the auxiliary motor between neutral and negative line. Continued movement of the controller handle weakens the auxiliary motor field, and as the inertia prevents its armature from speeding up rapidly, sufficient current flows to accelerate the main motor armature.

When the auxiliary motor field has been reduced to zero the main motor is running between neutral and negative line at approximately half voltage and speed. Up to this point the auxiliary motor has absorbed energy, its e. m. f. being in opposition to the line voltage and its speed has therefore increased somewhat. Further movement of the controller handle reverses the auxiliary motor field and gradually strengthens it. The auxiliary motor now acts as generator, and by reducing its speed, gives up the energy which was previously stored. Its induced e. m. f. is now in the same direction as the line voltage and therefore boosting this, so that the voltage impressed on the main motor continues to increase.

When the auxiliary motor field reaches full strength in the opposite direction its speed will have been reduced to approximately normal and its voltage added to the line voltage is approximately equal to the voltage between the outside main lines. The voltage of the main motor, being of approximate equality to the main line voltage, switch S_1 can be closed, making each machine run independently of the other, the main motor between the outside lines and the auxiliary motor between neutral and positive line. The switch S_1 is so connected and adjusted that it closes only when the controller handle is in running position and the main motor voltage bears a certain ratio to the line voltage.

To stop the elevator the operations are reversed by moving the controller to standstill position. During retardation the auxiliary motor voltage adjusts itself so that a regenerative current flows and a breaking torque is produced practically down to standstill.

It is obvious that the rate of acceleration and retardation follows a fixed law, precisely as in the system described by Mr. Bouton, if the controller is moved at once to the full running position in starting and to the off position in stopping. Equally, the rate of acceleration may be regulated by varying the resistance of a damper winding on the auxiliary motor field. Furthermore, the main current adjusts itself to retain approximately this rate under widely varying load conditions from large positive to negative or overhauling loads.

The acceleration and retardation curves and the speed-time curves when running at low speed can all be determined by mathematical analysis, but cannot be included in this brief discussion.

The current rating of the auxiliary motor depends on the relative amount of time consumed in acceleration and retardation and full speed running. At most it is equal to the current rating of the main motor, and as it is wound for one-half voltage its capacity is at most one-half that of the main motor. In case of d-c. power line the additional machine capacity is therefore less than one-fourth of that required with the control described in the paper. The losses, especially the standby losses, are, of course, correspondingly reduced.

Even when the supply is alternating current, the additional machine capacity and the losses can be materially reduced by using the auxiliary motor control and a synchronous converter for conversion from a-c. to d-c. current.

Fig. 2 shows the principal connections when the supply is a two-wire d-c. power line. In this case the main motor has two armature windings and two commutators connected in series during acceleration and retardation and in parallel when running at full speed. The switches S_1 and S_2 are double-pole. S_3' and S_4' always open and close simultaneously with switches S_3 and S_4 respectively. With these modifications the sequence of

switching operations is the same as before and the operation is essentially the same as in the case of the three-wire system already discussed.

E. M. Claytor: Referring to Fig. 5A in Mr. Bouton's paper, it may appear that the maximum rate of acceleration would occur earlier than it actually does because the peak torque is reached in ¾ second after the start, while the maximum rate of acceleration does not come until one second after zero time. The rate of acceleration is proportional to the net torque available for accelerating the total equivalent mass having linear velocity. The curve in Fig. 5A is somewhat misleading in as much as it is labeled "Torque of rope sheave" which might be taken to mean net torque on the ropes for acceleration. As a matter of fact this curve is the total torque at 1 ft. radius (developed by the motor armature) divided by the radius of the driving sheave.

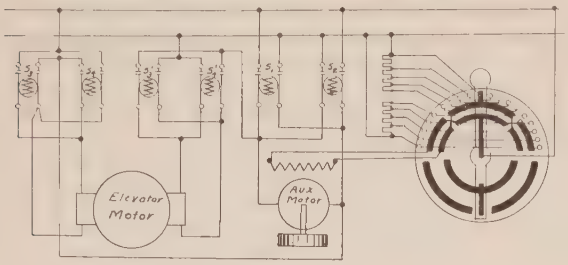

Fig. 2

The net torque is what is left of the torque curve in Fig. 5A after the torques due to the brake, bearing friction, bending of cables, and sliding friction have been subtracted. This difference is represented by curve 2 in Fig. 3 shown herewith, and it is the true net torque used only for acceleration. The peak of this curve comes at the same time at which the maximum rate of acceleration occurs in Mr. Bouton's Fig. 4 for balanced load, *i. .,e* where the slope of that curve is steepest. Curve 1 shows the car speed as taken from balanced load curve in Fig. 4. Assuming that this acceleration curve is correct, we derive Curve 2, which is the net accelerating torque, in the following way.

Pick out some point, say at 1½ seconds, where we may assume that the brake and static friction have reduced to zero, and draw a tangent as accurately as possible to the acceleration Curve 1. Next take the total motor torque at 1½ seconds and from it subtract the running friction torque of 460 lb. as obtained from a total torque curve (not shown) at some point corresponding to 3 or 4 seconds. The difference will be 2200 lb. which is the net torque for the point on acceleration curve corresponding to 1½ seconds.

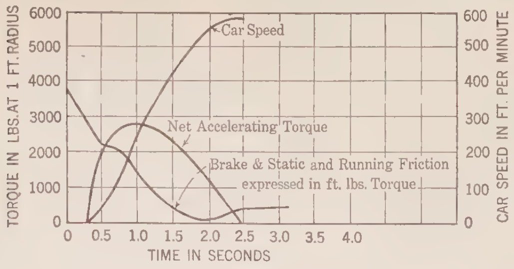

Fig. 3

We now have the rate of acceleration, and the torque which produces that rate. The unknown quantity is the equivalent mass having linear velocity. This we obtain from the simple formula—

$$M = \frac{T \times 32.2}{a \times R}$$

Where, M = lb. mass having linear velocity.
T = torque in lb. at 1 ft. radius
R = radius of driving sheave in ft.
a = rate of acceleration in ft. per sec. per sec.
and 32.2 = gravity acceleration constant.

The equivalent mass in this case was 11,350 lb.

After determining the mass, we rearrange the same formula above as follows—

$$T = \frac{M \times a \times R}{32.2}$$

By substituting known values of M, by previous calculation, R, by measurement, and a, by drawn tangents to the graphic test curve, we can solve for T which is the net torque Curve 2 in the sketch.

Having determined that component of the total torque curve which is used only for accelerating the balanced car, we subtract that from the total torque curve and we have Curve 3 left. This latter curve represents all friction or anti-torque. We know from other oscillograph tests that the brake reduces its torque to zero in 0.6 second. This means that the static friction is about 2000 ft-lb. at the start and it does not reduce to zero until a point corresponding to 1½ seconds. This indicates that the driving sheave and shaft have made more than a complete revolution before the static friction becomes zero.

The dip in the friction Curve 3 cannot be explained except by considering that oscillations or hunting occurs between accelerating torque and friction torque, or else the graphic meter had enough inertia in moving parts to overshoot the actual speed.

From the above analysis, we may draw the conclusion that

(a) An appreciable amount of power is wasted in friction during acceleration.

(b) A quick-acting brake on the pick-up is desirable.

(c) Anything done to reduce static friction will reduce the current and power peaks of the elevator motor.

W. F. Eames: In an effort to obtain what might be considered a perfect acceleration curve for an elevator, a number of curves have been analyzed, and although the results contain considerable speculation they are of interest in connection with the subject just discussed. It will be necessary first to define perfect acceleration and then to analyze the elements. Any remarks made in connection with acceleration apply in general equally well to retardation, as retardation may be considered as negative acceleration. Consequently we will consider only acceleration, and treat retardation as a special case.

Perfect acceleration as applied to elevators might be defined as that which will bring an elevator up to speed in a given time without discomfort to the passengers. Assuming that the speed of an elevator can be made to follow any curve in going from zero speed to full speed, some method must be used to select the best one. The problem of comfort to a passenger seems to be tied up psychologically in some measure with the idea of falling. That is, if the motion of the car is such as to suggest falling, a feeling of discomfort is produced. Falling is concerned with a high rate of acceleration especially a high rate suddenly applied, which corresponds to a high rate of change of acceleration. The continuous curve that represents values between zero and a maximum has necessarily an S shape and most of them can be represented by some combination of the powers of X in the general equation y = function of x.

Several curves have been plotted from equations of the form

Velocity	$= K_1 t^2$	(Parabolic)
"	$= K_1 t^2 - K_2 t^3$	(cubic)
"	$= K_1 t^2 - K_2 t^4 + K_3 t^6$.	(cosine)

and were all found to lie very close together, and to the eye showed no points where noticeable difference will be felt if an elevator were accelerated along any of them. Plotting the first and second derivaties the parabolic curve showed the highest accelerating rate and the lowest rate of change of acceleration.

The cubic equation gave the opposite conditions and the cosine lay between.

Various observations indicate that the high rate of change of acceleration is more objectionable than a high rate of acceleration. If this is true the parabolic form is the most desirable of the three functions. It was also found that the variable-voltage elevator acceleration lies very close to the parabolic form at balanced car conditions and when lifting full load departs only slightly from it. Fig. 4A herewith shows the velocity curve for the variable voltage elevator rated at 2000 pounds at 550 feet per minute that has just been discussed by Mr. Bouton. The dotted curve shown in the same figure is a parabolic curve, that passes through the zero, mid-point, and full speed values of the velocity curve. Figs. 4B and 4C. shows the first and second derivatives, or the acceleration and rate of change of acceleration. The maximum acceleration is (7.5 ft./sec.)² and the maximum rate of change of acceleration is (6.4 feet/sec.)³. As the operation of the car is very comfortable with the conditions shown, higher accelerations can be used than these shown and it is probable that with the variable-voltage system of control that a car can be accelerated to 650 to 700 ft./min. in 2½ seconds without discomfort to the passengers. In this connection, however, it should be mentioned that as the rates of acceleration are increased other limiting factors appear in addition to the discomfort felt by the passengers. For example, slipping of the

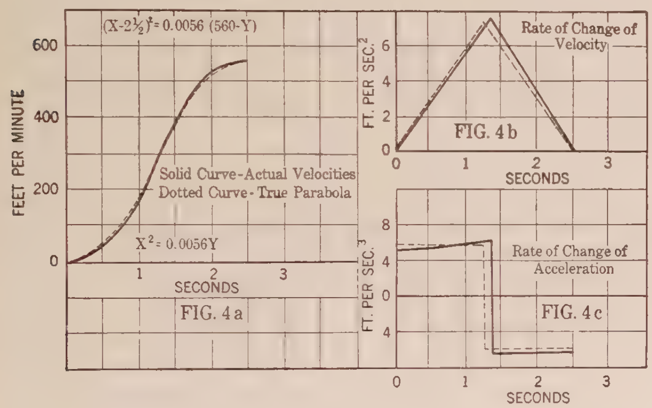

Fig. 4

cables on the driving sheave occurs if the retardation rate is too great. This decreases the life of the cables. Also larger equipment is required when these high rates are used, than is required with the lower ones. This point becomes important especially when the elevator cab and other parts have a large inertia.

The above considerations apply equally well to retardation of the elevator. However, the rates used in retardation can be somewhat higher than those used in acceleration without causing discomfort. The reason for this is probably that a greater sense of security is felt because the car is slowing down. Although no extended experiments have been tried it has been found that, if a person shuts his eyes, much less discomfort is felt in an elevator using high rates of acceleration. If maximum rates are to be demanded in the future, it may become necessary to take steps to prevent the passenger seeing the floors passing. If this is done it is likely that the accelerating rates can be raised as high as there will be any occasion to use.

M. A. Whiting: For the benefit of those who are not familiar with the term, nor with the system which it covers, it may be well to explain that the system described by the name "variable voltage control" is not an entirely new system first developed to meet elevator conditions. The system thus referred to is, in its fundamentals, the same system of motor control which is commonly called generator-voltage control, generator-field control or Ward-Leonard control. The comparative antiquity of this system is shown by the fact that it helped sink the Spanish fleet off Santiago de Cuba in 1898. Merely as an indication of the extent to which this system is now used it may be mentioned that, over a period of 16 years, one manufacturer has built, or is now building, for steel-mill and mine-hoisting service alone, over 70 equipments totaling over 110,000 h. p. The corresponding totals for the other manufacturers covering these items and a complete list of other classes of service to which this system has been applied would also be impressive.

The new development presented in Mr. Bouton's paper is,

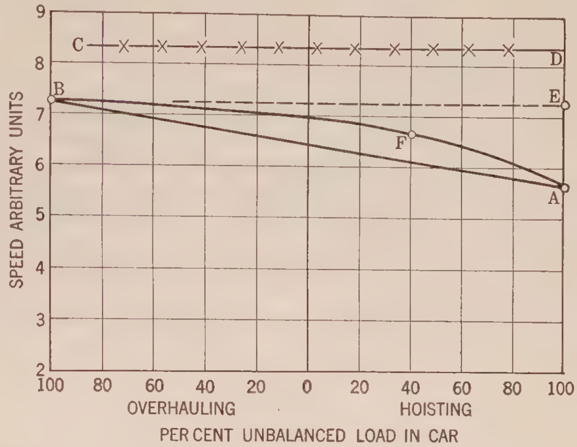

Fig. 5

therefore, not the fundamental system of "variable-voltage" or generator-voltage control itself but is rather the extensive application of this system to elevators. The problem, or the accomplishment, should not be belittled, however. Some of the previous practise in the application of generator voltage control could be followed but some special problems were presented by the requirements of elevator service, and it has, therefore, been necessary to devise new practises.

One of the principal problems is that of speed regulation over the range of loads handled, which is discussed by the author

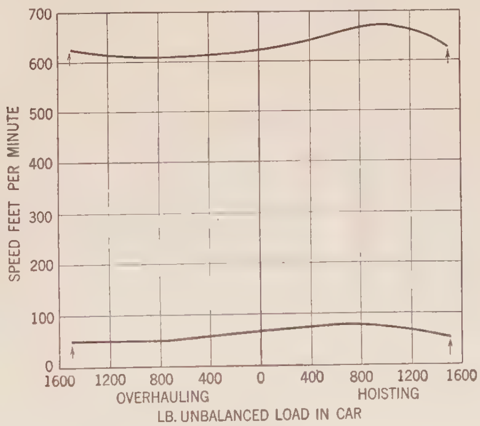

Fig. 6

under "Requirements of Elevator Service" and under "Characteristics and Operation." Attention is called particularly to the author's Fig. 7. The speed regulation shown on the low-speed controller point is much closer than is obtainable with any practicable rheostatic machine and provides a correspondingly greater ease of control in making landings. However, let us examine the author's Fig. 7 more closely. As the results are given in per cent of motor torque, an interpretation is required. It is reasonable to assume that 100 per cent positive torque cor-

responds to the hoisting of an elevator load not exceeding normal capacity; then when lowering the same elevator load, the motor torque will be not less than 60 per cent negative. The speed at 100 per cent load is about 6½ rev. per min. and at 60 per cent negative load is about 11½ rev. per min., or about a 75 per cent rise in speed from full load "up," to the corresponding load condition "down." If this speed regulation curve could be made flat at all loads, this would be found very useful in attaining a still greater ease of control for making landings.

On the full-speed point, the regulation shown by the author's Fig. 7 is from 64 rev. per min. at 100 per cent load to 82 rev. per min. at 60 per cent overhauling load, or a rise of 28 per cent. Let us consider further just what such a speed regulation at full speed means in the operation of an elevator.

Fig. 5 herewith shows a speed regulation curve for a hypothetical gearless elevator plotted to per cent unbalanced load in the car. The speed regulation (28 per cent rise from full load hoisting to full load overhauling) is assumed to be the same as that in the author's Fig. 7. The speed curve may be considered to be bow-shaped, as in the author's Fig. 7, but I believe that a nearly straight inclined line from A to B is equally typical, particularly if an extra contact on the speed governor is not used to operate within this speed range. Line C-D represents the speed at which the overspeed governor will set the safety clamps. It is com-

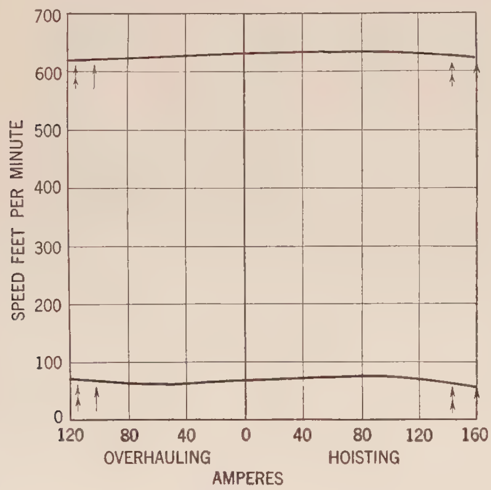

Fig. 7

monly considered that the margin of speed, B-C, between maximum overhauling speed and the final emergency operation of the governor, should be not less than 15 per cent in terms of speed B. Let us assume also that the elevator rides comfortably and can be controlled without difficulty when overhauling at speed B. Now if a speed as high as B is suitable in all repsects when thus lowering maximum load, a speed as high as B is also equally suitable when operating at balanced load or when hoisting full load; in other words, if speed B is right, a speed curve B-E is right.

The advantage of a flat speed-regulation curve, as B-E, will be greatest on express elevators during the rush hour going in. If the load goes up at speed A, and the empty car comes down (against the overbalance of the counterweight) at speed F, the average speed up and down will be only 85 per cent of the permissible speed B. Allowing about 30 per cent standing time and 70 per cent running time for rush-hour express operation, the loss of service per elevator due to the poorer regulation, compared with perfect regulation, is about 11 per cent.

In order to provide the maximum service possible from an equipment of a specified maximum overhauling speed, and also in order to obtain further improvements over previous equipments in ease of handling the elevator, an improvement in generator-voltage control has been developed by which regulations are obtained which approach closely the ideal which I have just described. I intend to prepare a technical paper in the near future covering this development, but some of the results are presented herewith.

Fig. 6 herewith shows results obtained on the first commercial installation embodying this development, the elevator being rated 600 ft. per min., 2500 lb. live load and counterbalanced for 40 per cent of the live load (maximum unbalance 1500 lb.). On the first or lowest speed point, the speeds at maximum load hoisting and maximum load overhauling are equal at 50 ft. per min., and the prevailing speed over the entire range of overhauling loads is actually *lower*, as an average, than over the range of hoisting loads.

On this same equipment, in Fig. 6, the full speeds at maximum load hoisting, at balance and at maximum load overhauling are equal at 625 ft. per minute, and the overhauling speeds are lower, on the average, than the hoisting speeds.

Further developments of this system have been made and embodied in equipments of more recent manufacture. A shipment of three such equipments was made after only routine factory tests on the individual parts of the equipment; the machines were placed in successful commerdial service promptly, without difficulty and without personal assistance from headquarters.

At the first opportunity, extensive factory tests were made on an equipment in accordance with these further developments. Numerous proportions and adjustments were studied, and a typical set of adjustments gave results as in Fig. 7 herewith. Since predictions may differ as to the mechanical losses in an elevator installation beyond the traction-motor armature, the results in Fig. 7 are given in amperes, as taken. If the mechanical efficiency is assumed as 80 per cent, the rated load of the elevator is represented by 160 amperes hoisting and 102 amperes overhauling. Or, on an assumed mechanical efficiency of 90 per cent, the corresponding loads will be 142 amperes hoisting and 115 amperes overhauling. On the former basis, when hoisting full load on the first speed point, the speed is 55 ft. per min. and when lowering full load, the speed is 67 ft. per min., an increase of only 12 ft. per min. at full load overhauling. On the basis of the higher mechanical efficiency, this regulation is even closer. If, on this regulation curve a horizontal straight line is drawn at 65 ft. per min., the speed at nearly all positive loads is slightly *above* and at nearly all negative loads is slightly *below* this average line. For all practical purposes, therefore, the speed regulation on the first speed point is flat over the entire range of loads.

The regulation on the full-speed point for the equipment in Fig. 7 (assuming 80 per cent mechanical efficiency, which is the less favorable case) is from 615 ft. per min. at full load hoisting to 620 ft. per min. at full load overhauling. The maximum speed, 630 ft. per min., occurs at balanced load and various heavier loads going up. The significant speed regulation is therefore 1 per cent, from full load up to full load down.

After this equipment (as in Fig. 7) is installed, results of its operation in actual service will be presented in the paper which I intend to prepare. In that connection, the system of control will be described and explained.

J. J. Matson: In Figs. 14 and 16 Mr. Bouton shows results of tests to determine elevator power consumption with various loads and stops per car mile. As the curves are obtained from tests the power consumption undoubtedly contains the motor-generator losses only during the period of test. Assuming this is true, the results greatly favor the variable-voltage control system. By this, I mean that if the power consumed, the stops made, the miles traveled and the average elevator load for one day were measured and the kilowatt hours per car mile calculated, the result obtained would be higher than is given in Mr. Bouton's curves. The reason is apparent if one stops to consider the actual

cycle of operation for an elevator which consists of some time running, and some time standing (Includes time required for receiving and discharging passengers). During the standing time, which may be as high as 50 per cent of the total, the motor-generator set will surely be running and taking power. This power would, of course, be shown in the all-day run but when a test was run for power consumption, the running-idle losses of the motor-generator set would not be included as the elevator would be operated continuously until sufficient readings were taken to obtain the power-consumption values. The best way to compare power consumption for variable-voltage and rheostatic controlled elevators is on an all-day basis. Even under such conditions, the variable-voltage control shows the lowest power consumption, the saving increasing as the stops per mile increase.

A great deal of importance has been attached to elevator power consumption by all interested parties. In reality this is not borne out by a careful consideration of all factors. For example, assume a 20-story building having a hatch 7 ft x 6 ft. and the floor space renting for about \$3.00 per sq. ft.; the elevator to cost \$18,000; the actual charges then become on a yearly basis:

Rentable floor space occupied by elevator	\$2520
Interest depreciation, insurance, etc., (15%)	2700
Operator's salary	750
Maintenance, etc	300
Spare parts, re-roping, etc	350
Power bill (20 miles per day, 2.5 kw-hr. per car mile, 300 days per year and 2c. power	300
Total	\$6920

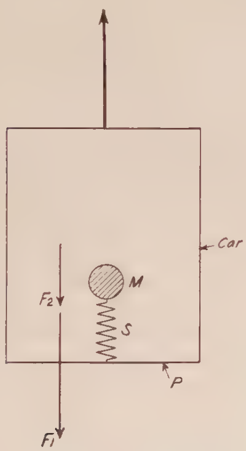

Fig. 8—The Gravitation Field in an Accelerating Elevator Car

Thus, the power bill is the small part of the total yearly elevator bill, approximately 4.0 per cent.

Fig. 11 shows the regulation on a rheostatic-controlled elevator motor. The regulation between 100 per cent motor torque and 64 per cent generator torque (this assumes a mechanical efficiency of 80 per cent) is approximately 63 to 83 rev. per min. or 31.8 per cent. Tests on an elevator which has been installed about 18 months, show the speed regulation (without centrifugal speed governor) to be as follows: 100 per cent motor torque 64.5 r. p. m. Zero torque 62.0 r. p. m., and 64 per cent generator torque 68.5 r. p. m. This is regulation of 6.2 per cent. It is interesting to note that full-speed acceleration was obtained in about 3¼ seconds and with perfect comfort to passengers.

Bassett Jones: I want to add something to Mr. Eames' discussion of Mr. Bouton's paper. The fact that the most suitable time-velocity characteristic of a passenger elevator is a reversed parabola may be deduced directly from the mechanics of the passenger's body. This I have already discussed in "The Time-Velocity Characteristics of High Speed Passenger Elevators," *General Electric Review*, P. 111, February 1924.

In Fig. 8 shown herewith the mass, M, represents the mass of the passenger's body. The spring, S, represents the elastic elements of his bodily frame. If the car be standing still or traveling at any constant velocity, the force F_1 acting on M and causing a compression of S is the gravitational field of the earth. If the car accelerates on the up motion or retards on the down motion, a force, $F_2 = M\,a$, is added to F_1 and the spring is further compressed. If the car accelerates on the down motion or retards on the up motion, the force F_2 is deducted from F_1 and the spring expands.

Obviously if this force, F_2, is applied or removed suddenly as by constant acceleration, the resulting shock to the passenger's body will be uncomfortable. Therefore, it should change from zero to a maximum, and from a maximum to zero in some gradual manner, and it seems reasonable to suppose that if this change be constant, the best conditions will result.

This requires that the *rate of change in acceleration* (or retardation) *be a constant*, that is,

$$\frac{d\,a}{d\,t} = p,$$

where p may be called the *physiological constant.* Therefore, if S be distance,

$$\frac{d^3\,S}{d\,t^3} = p \qquad (1)$$

From this, the velocity, V, in ft. per sec. at any time, t, is

$$V = 1/2\,p\,t^2 + C_1\,t,$$

and $C_1 = V_m/t_m - 1/4\,p\,t_m,$

or $V = 1/2\,p\,t^2 + (V_m/t_m - 1/4\,p\,t_m)\,t,$

where V_m is the maximum velocity in ft. per sec. attained in time, t_m, given in seconds.

Evidently the only possible case is when

$$V = 1/2\,p\,t^2, \qquad (2)$$

giving

$$(V_m/t_m - 1/4\,p\,t_m) = 0 \qquad (3)$$

Therefore the time-velocity characteristic is a parabola. Also maximum acceleration reached is

$$a_m = p\,t_m/2.$$

Equation (2) holds between $V = 0$, $t = 0$ and $V = V_m/2$, $t = t_m/2$. From $V = V_m/2$, $t = t_m/2$ to $V = V_m$, $t = t_m$ the curve is reversed. A single equation for the entire curve may be developed, but is not a practical necessity.

From (3) it is obvious that

$$V_m = 1/4\,p\,t_m^2,\; p = 1/4\,V_m/t_m^2,\; t_m = 2\,(V_m/p)^{1/2} \qquad (4)$$

Therefore if any two conditions, V_m, t_m or p, are given, the remaining condition is fixed. A few such ideal time-velocity characteristics are given in Fig. 9. The whole matter being more completely discussed in the article mentioned above.

From a practical standpoint it is not essential that the parabolic form be maintained except during the initial and final parts of the acceleration. Between these, the acceleration may be constant, or nearly so. Probably the time-velocity curve should approximate very closely to a parabola during the first and last 0.5 second of the acceleration period.

Obviously, for any given value of V_m the smaller is p the longer is t_m, and the round trip time for a given traffic will be increased.

Consequently, where comfort is a matter of moment, as in family hotels, hospitals and the like, a value of p smaller than can be properly employed, for instance, in office building equipment, must be used and the rapidity of service correspondingly sacrificed.

The next question is, what shall be the relative values of p in two such cases?

Having established as above, the manner in which the kinetic energy of motion must be communicated to the passenger's body, it is necessary to put a limit on the total amount that

can be safely communicated in a given time without over stressing the elastic elements of the passenger's body. Given a certain time of acceleration, the impressed kinetic energy varies as the square of the velocity attained in this time, or as p^2. Mechanically speaking, the reverse of this case is precisely the same as determining the capacity of oil buffers for a given retardation time. If the oil buffer is to bring the car to rest in the same time, irrespective of the velocity, then, if the velocity of the loaded car be doubled, the capacity of the oil buffer must be quadrupled.

So, probably, if in two cases $p = 10$ and $p = 20$ for the same value of t_m, the discomfort of the passenger due to muscular stress, may be assumed to be as 100 is to 400 in the two cases. In the latter case he will experience four times the discomfort he experiences in the first case.

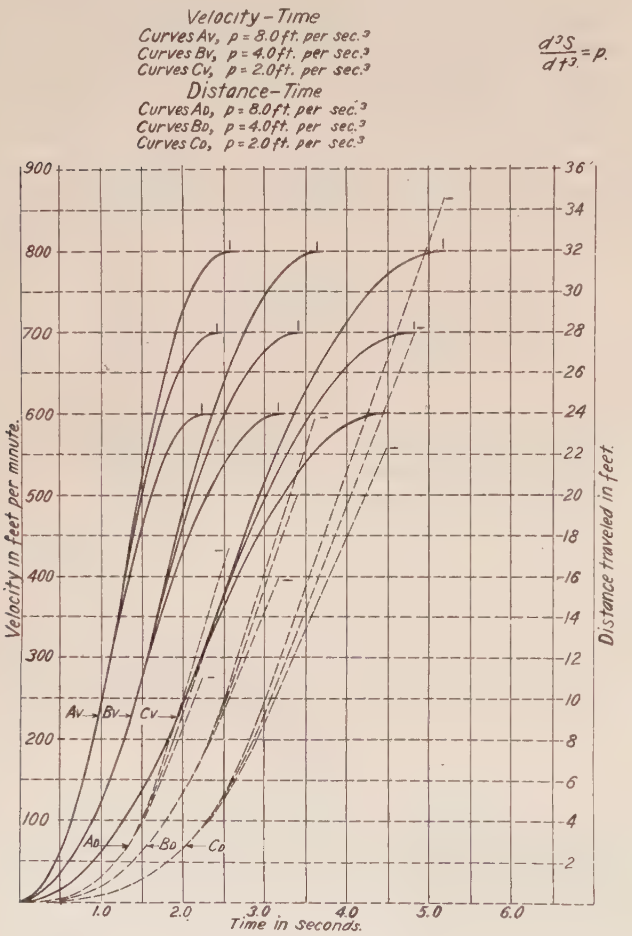

FIG. 9

If, the ratio of comfort in the two cases is to be as 2:1, then, also the corresponding values of p are 20 and 14.

Assume that $V_m = 11.66$ ft. per sec. (700 ft. per min.) then from (4), and the values of p (20 and 14) given above, $t_m = 1.53$ and 1. 3. The latter of these is 19 6 per cent greater than the former.

Of course much of the above is theoretical in the sense that it is based on an assumed simplicity in the mechanics of the passenger's body that it does possess. Also, it requires a form of torque-time characteristic of the hoisting-engine motor that, so far as I know, can only be obtained by special adjustment and for one particular set of values of V_m and p for anyone motor and control, and for some one value of the load.

However, this discussion is intended merely to draw attention to the real problems faced in attempting to attain high velocities and rapid acceleration in elevators. Definite solutions must wait on the necessary physiological tests required to set up the values of p.

A. A. Gazda: Looking back over the experience of the past three years in the installation and operation of upwards of 150 elevators controlled by the variable-voltage system, the one outstanding feature is its adaptibility to a broad range of applications. On one hand the advantage of smooth control for high-speed machines is quite apparent but on the other hand the feature of definite and positive speed points has been utilized not only in slower-speed passenger elevators but also in high-grade freight installations. For automatic or push-button controlled elevators particularly, we have found it of considerable advantage to have a system at hand whereby two or more definite speeds can be set at convenient values and thus insure accurate stops even under changing load conditions. Hitherto, the nominal operating speed of automatic elevators has been limited by the design of induction motors with certain sub-synchronous speeds and in the case of direct-current machines by the lack of smooth transition from one speed to another. Introducing a motor-generator set (and the variable-voltage system) as outlined in Mr. Bouton's paper has solved both the problem of definite speed points and smooth transition. It is only necessary to locate the desired values on the generator-field rheostat and depend upon the time element of the magnetic circuit to make the swings smoothly. In accomplishing this, permanent damping windings must be provided. Also final adjustments may readily be made by placing discharge resistors across the shunt fields. If the time constants are too great the elevator operation will be sluggish. On the other hand short time constants throw severe peak loads on the commutators of both the generator and the elevator motor and if these peaks are frequent or of sufficient intensity the commutators will not stand up. This statement is made not to bring out disadvantages of the system but rather as a factor that must not be overlooked.

Another important field of application for this system lies in freight elevators which must be held level with the floor landing automatically. As shown in Fig. 7 of Mr. Bouton's paper a stable low speed can be maintained throughout the torque range and thus insure accurate stops. In such applications the problem really lies in changing the motor torque quickly on account of static friction. This has been accomplished by the proper choice of the generator series field and also by the use of momentary contact switches in the main control scheme. Our experience has demonstrated that this problem can be solved and there are now several installations of this type in successful operation.

In high-speed elevator work we find that the continued successful operation of the cars depends largely upon the care taken in maintaining the original adjustments particularly on the controller. Our experience with variable voltage installations has demonstrated that the original control adjustments are of a permanent character which do not change as contacts wear. Even as originally installed by average elevator constructors, the system is almost fool-proof and we have often been agreeably surprised by the smooth acceleration and deceleration obtained by inexperienced men. This ease of installation and operation is a factor of considerable importance from the standpoint of the elevator manufacturers particularly when it is so difficult to find competent mechanics.

W. L. Atkinson: Field experience with the system of control described by Mr. Bouton has indicated that we have here a means of obtaining operating characteristics in an elevator, not possessed by any other known means of control. While the comparative economic advantage for any given number of stops per car mile can be very readily analyzed and definitely stated, the important feature of smoothness of operation through the accelerating and decelerating periods, contributed by this method can only be demonstrated by actual experience with elevators in the field.

The company with which I am connected, has installed and in operation fifty-two elevators equipped with this system of control, operating at 400, 500, 600 and 700 ft. per minute, and in every installation a distinctive and characteristic smoothness is noticeable throughout the starting and slowing down periods. In the highest developed type of rheostatic control, making use of all the refinements which experience has shown to be of advantage we cannot attain a smoothness of operation with rheostatic control comparable with that quite ordinarily possible with the variable voltage scheme here described.

While we have been limited heretofore, to a maximum speed of about 600 ft. per minute, or in exceptional cases to 700 ft., we are now enabled by this means, we are quite sure, to go to speeds much beyond this limit without occasioning discomfort to passengers, and with the certainty of making definite stops under all conditions of loading.

Those of you who have worked on the traffic problem involved in moving the occupants of a densely populated tall modern office building in or out of the building, over the usual peake of say 20 to 40 minutes, will readily appreciate the value of any system of elevator control that offers a practical means of cutting down the time of a round trip or cycle of operation.

With modern elevator machinery there is no difficulty encountered in operating at any speed we may wish, once that uniform speed has been reached. The limitation has rather been imposed by the means available for bringing the car up to speed or slowing it down to a final stop, quickly and without discomfort to the passengers.

In a recent trial on an elevator in regular service equipped with the variable-voltage system of control, and having a nominal speed of 600 ft. per min., the car was operated at 850 ft. per min. without the occupants of the car noticing or being aware of the fact that it was not operating at the usual speed. From such data and experience in the field we are entirely confident in predicting successful operation of passenger elevators up to a speed of 1000 ft. per min.

Laurence D. Jones: Mr. Bouton's paper describes the application of the well known system of generator voltage control to the operation of electric elevators. When this system of control is used with any application where rapid rates of motor acceleration and retardation are required, these rates are in most cases dependent upon the rates of building up and dying down of the generator field.

As pointed out by the author, this fact offers one of the principal advantages of applying such a system of control to elevator service because it insures very smooth acceleration and retardation.

The inherent rates of change of generator voltage are dependent on the time constant of the field circuit which, in turn, depends upon the proportion of resistance and inductance in the circuit. It is possible to change the time constant of a field by changing the proportions of resistance and inductance. The usual method is to increase or decrease the resistance as the inductance is not so easily changed. The resistance may be increased by placing a resistor in the circuit and may be decreased by placing a short-circuited damping winding around the poles.

From the usual theory of building up of current in a circuit having resistance and inductance, the time required to reach a constant value depends upon the proportion of L to R. Bearing this fact in mind we find it rather difficult to understand how Mr. Bouton obtained the results shown in Fig. 3 of his paper which indicates that the use of a short-circuited damping winding has changed the rate of building up, but has not affected the time required for the voltage to reach a constant value. It is possible that the author has used some special means for producing the effect shown. If so, a description of how this was accomplished would prove of interest.

Similar tests which have been made under the same conditions as those described in Mr. Bouton's paper show a very material difference in the time required for voltage to reach constant value, with the field damped and undamped. In this case the time was 4.4 seconds with the damping winding in use and 2.0 seconds without this winding. Figs. 10 and 11 shown with this discussion are oscillograph records of the building up of field current and armature voltage of a generator having its field undamped and also damped. Fig. 12 is a comparison of the voltage curves for the two cases. The general conclusion from these tests is that the use of a damping winding is of value as a means of changing

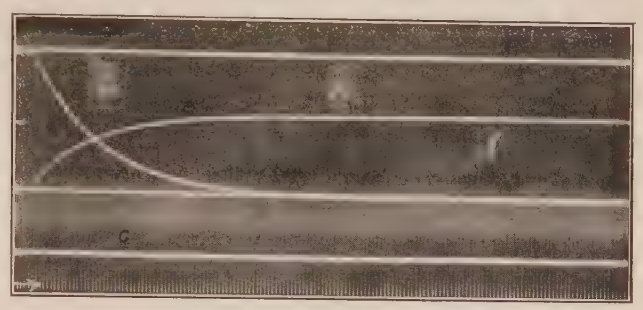

FIG. 10—OSCILLOGRAM SHOWING BUILDING UP OF GENERATOR FIELD CURRENT AND ARMATURE VOLTAGE WITHOUT DAMPING WINDING ON FIELD

Curve A—Armature voltage, 230 volts maximum.
Curve B—Field current.
Curve C—Timing wave. (40 cycles.)

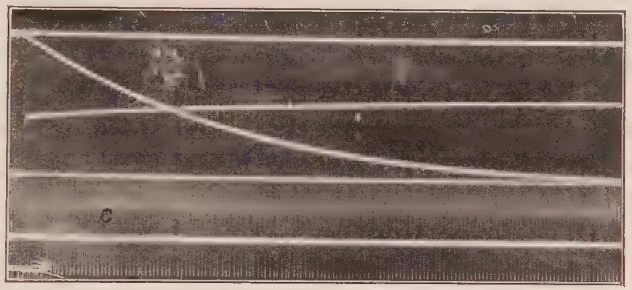

FIG. 11—OSCILLOGRAM SHOWING BUILDING UP OF GENERATOR FIELD CURRENT AND ARMATURE VOLTAGE WITH DAMPING WINDING ON FIELD

Curve A—Armature voltage, 230 volts maximum.
Curve B—Field current.
Curve C—Timing wave. (40 cycle.)

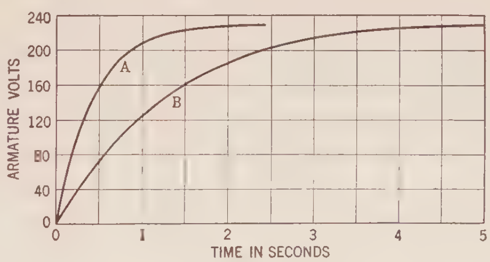

FIG. 12

the time constant of the field so as to obtain the desired time for accelerating to full speed but has very little effect upon the shape of the curve.

From Part III of the paper one is likely to gain the impression that the traction motor will have acceleration and retardation curves of the same shape as the building-up or dying-down curves of the generator voltage and that these curves are independent of the load. That this is not the fact is quite evident if we compare the shape of the acceleration curves in Fig. 4 with

the curves in Fig. 3. The principal reason for the disagreement is that the shape of the speed curves is modified to some extent by voltage drop in the armature circuit. With further reference to Fig. 4, I would like to ask Mr. Bouton why a longer time is required for the motor to accelerate a loaded car going down to a given speed than is required to accelerate a balanced load to the same speed.

E. B. Thurston (by letter): Mr. Bouton's paper leaves the impression that an elevator operated by a direct-current motor, supplied from a motor-generator set, should be called an alternating-current elevator, in case the motive power for the generator set be alternating current. It seems this impression should be corrected, because elevator motors for years have been supplied from a-c. to d-c. motor-generator sets, and have never been considered as alternating-current elevators. (Indeed were the variable-voltage generator driven by water or steam power the elevator would be called a hydraulic or steam elevator with the same line of reasoning.)

Fundamentally the only elevator that can be truly called an alternating-current elevator is one in which the elevator machine is driven directly by an alternating-current motor.

Comparing the two systems—variable voltage and the straight alternating-current, as defined in the preceding paragraph—it is seen that the variable voltage as given in the paper consists of six main elements, while the straight alternating current consists of but two, the elevator motor and its controller.

Although the paper under consideration refers to the alternating-current elevator equipment, it is noted that none of the test information contained therein gives any consideration to an alternating-current power supply, but deals only with equipment requiring direct current. If the paper leaves the impression that the curves apply to equipment having an alternating-current supply it is misleading, for the amount of energy returned to the line during slow-down will certainly be somewhat different from an a-c. to d-c. motor-generator set. Another very important consideration is the fact that the power factor will be very low during average elevator operating conditions, and idle and slow-down periods, which will be 90 to 95 per cent of the total time in service.

The paper compares only two types of control—variable-voltage and rheostatic, and these with direct current supplied, whereas it is a fact that the standard shunt-control direct-current elevator unit, consisting of the two main elements of motor and controller, shows in regular service an energy consumption still lower than either of these.

The tests given in the paper are interesting, but actually of little value even for comparison with other types of control.

Energy-consumption tests, to be of value, must show what the particular types of control under comparison are doing in actual service, where a corresponding number of hours per day, miles per day, stops per mile and kilowatt hours per car mile over a number of months are recorded. This recorded information will represent quite accurately average conditions, and will be of great value to engineers in general.

The different types of elevator control might more fittingly be compared by giving consideration to an increased number of items as follows:

Economy as to first cost.
Economy as to maintenance.
Economy as to energy consumption.
Economy as to space.
Safety.
Simplicity.
Number of main elements.
Total number of parts.
Continuity of service.
Speed regulation.
Accelerating and decelerating characteristics.

As engineers we instinctively aim towards ultimate simplicity of equipment with maximum safety and refinement of operation combined with a minimum kilowatt-hour consumption for regular operating conditions.

It is, therefore, self-evident that a straight alternating-current elevator with only two main elements, which will give any desired car speed with positive control, smooth, quiet, rapid acceleration and deceleration, and a low overall operating cost as well as all of the safety requirements, is a goal towards which we, as electrical engineers, should turn our interest and attention.

E. W. Seeger (by letter): Although the acceleration of an elevator equipped with variable-voltage control is exceedingly smooth, it is possible to get practically the same results with other types of control. In decelerating and stopping, however, the variable-voltage system has a decided advantage because of the possibility of obtaining a sustained braking effect and a stable slow speed. The quick acceleration and retardation possible with this type of control will probably lead to the more general use of high-speed elevators for local service.

It is always difficult to compare data on the power consumption of elevators because so many factors, other than the electrical equipment, affect the result. The exact method of making the test plotted in Fig. 14 is not stated. If the load were placed on the car and the elevator then started and stopped the required number of times, the test would not show results which would be obtained in actual service, but would favor the variable-voltage equipment.

Another factor which will affect power consumption is provision for night service in office buildings. Although it is possible to start the set each time the elevator is required, it is doubtful if this practise will be followed and probably one set will be allowed to run.

After acceleration is completed and the motor is running at full speed, the variable-voltage system, due to the losses in the motor-generator set, is probably the least efficient of any of the accepted methods of control.

Even after taking the above factors into consideration, the variable-voltage system will undoubtedly show a saving on any installation where a gearless traction machine is justified. This is particularly true with "green" operators because the power required for inching is less.

With slower-speed elevators driven by geared machines, it is more difficult to justify the use of the variable-voltage system. The rheostatic losses are, in general, a much smaller percentage of the total power, landings are easier to make, and the service is less frequent. It follows that the maintenance expense is also smaller.

There is, therefore, a very definite field for the two speed a-c. motor on moderate-speed geared elevators. The acceleration and deceleration obtained with this type of equipment are as satisfactory as obtained on most d-c. installations. The average a-c. installation, however, is comparatively noisy, and for this reason the variable-voltage system has been installed in some cases where quiet operation is essential.

In the majority of variable-voltage equipments which have been installed, the car operating switch has been used, not only to control the contactors on the board, but also to vary the generator field resistance directly.

The generator field resistance is usually placed on the car, and inasmuch as a number of resistance steps are used, there is considerable wiring on the car which is comparatively inaccessible. The writer believes that a more satisfactory arrangement is to have the car-switch-control multi-point relays placed on the control panel. With this arrangement, only one set of resistance is required and it can be placed on the control panel rather than on the car, where space is at a premium.

B. M. Jones (by letter): It has been my good fortune to do some work on a variable-voltage elevator built by Mr. Bouton's company, and it was a pleasure to see the ease with

which the elevator was controlled and the smoothness of its operation.

The writer has also done considerable work on some of the early two-speed a-c. elevators using squirrel-cage motors having two speeds, covering a range of approximately three to one. This means that the a-c. motor has two primary windings. For starting the motor it is thrown on the low-speed winding and as the car accelerates the motor is automatically transferred to the high-speed winding through resistance which smooths out the acceleration. The star point of the windings is brought out of the frame of the motor and the resistance connected in these leads before the starting connection is made. Magnetic contactors short circuit this resistance in steps to accelerate the car. When switching from high to low speed, the resistance is thrown in the high-speed winding before the latter is thrown on the line, thus smoothing out the change in speed from low speed to high.

In connection with these two-speed elevator motors, as well as with any elevator motor, the number of stops per minute and the duration of the stops have a great effect upon the heating of the motor, as does the class of building in which the elevator operates. For example there are some department stores five or seven stories in height in which during non-rush periods the car only pauses at each floor, and, seeing no passengers, the operator proceeds on to the next floor. This constitutes a full stop and start, but with very little rest period. This is very severe duty on the motor and is considerably different from that in a tall office building where the elevators runs three, four, five, or, in some cases, ten, floors without a stop, thus operating the motor a great portion of its operating time at a high speed and consequently deriving the benefit of its ventilating effect.

The question of first cost of an elevator installation is a quite important one and the method of drive influences this cost somewhat. These points were not touched upon in this paper. It is also very interesting to know the power consumption of elevators per car mile, and the comparative power consumptions of variable-voltage d-c. elevators and two-speed a-c. elevators, as well as the amounts of maintenance required on these two schemes.

The question of speed of elevators is very interesting, especially for a tall office building where the ability to handle the peak load in a space of half an hour two or three times a day is very important. However, the ability to operate an elevator at such a speed that the operator can make the landing at the floor accurately without a great amount of juggling up and down, to which passengers object strenuously, is very important and should be kept in mind by the elevator designers as well as the motor and control designers when laying out elevators for a tall office building.

E. M. Bouton: Mr. Whiting has shown some very interesting results obtained with variable voltage control, by paying particular attention to the details that affect the regulation of the motor. Unfortunately, he has not described the method by which he obtained the results.

In general, the regulation of the elevator motor can be improved by increasing the compounding of the generator or by using control contacts which manipulate the generator or motor fields in response to changes in motor load or speed. The generator compounding may be accomplished by putting series turns upon its own field poles or by putting these series turns upon an auxiliary generator which excites or affects the excitation of the main generator. If the generator is compounded so as to have a flat speed torque curve at high speed, it will probably have a rising curve at slow speed. This is because the generator fields are more nearly saturated at full speed and a given number of series turns is more effective at the lower saturation. It is entirely practicable to compound the machine in this way, except that if carried too far it has a tendency to make the equipment unstable.

I believe that a little further discussion of Fig. 7 and Fig. 11 would be helpful. Curve 1 in Fig. 11 shows the inherent regulation of a gearless machine at full speed without the corrective effect of any speed governor contacts when connected to a constant potential of 230 volts. The regulation at low speed with armature series and shunt resistance will be as shown by Curve 2.

The test illustrated in Fig. 7 consisted in taking the same machine and driving it with a variable voltage generator. The generator compounding was so adjusted as to give approximately the same regulation at high speed as was obtained on the constant voltage supply. The inherent regulation at low speed is then shown by Curve 2. A comparison of curves 2 in Fig. 7 and Fig. 11 shows the advantage that variable voltage control has over rheostatic control in making landings when adjusted for the same regulation at full speed.

It was not the purpose of my paper to show the maximum improvement over rheostatic control that could be obtained, but rather to show that the variable voltage system has certain inherent characteristics that make it superior to other systems. It is entirely possible, as is shown in Mr. Whiting's discussion, to make the regulation at full speed as good as is desired. I wish to state, however, that additional complications are involved if extremely close regulation is desired.

The tests shown in Figs. 14 and 16 include the motor-generator losses only during the period of test. For this reason, in actual service the all day power consumption would be somewhat higher. For example, if the elevator runs 20 mi. in a 10-hr. day, the no load losses will be, (at 1.25 kw. per elevator)—$1.25 \times 10 = 12.5$ kw-hr. total for the day. This loss must be distributed over the 20 mi. traveled and will be $12.5 \div 20 = 0.625$ (625/1000) kw-hr. per car mile for the idling losses. It would not be right, however, to add all of this to the test value shown in Fig. 14 since time was actually consumed in making the test. It would probably be fair to add ½ of this value or approximately 0.3 (3/10) kw-hr. per mile to the test value to obtain the actual power consumption of an elevator operating on the schedule outlined above. For night service the motor-generator sets car be shut down so that the losses do not occur except while the car is running.

I wish to point out also that the test results shown in Fig. 15 for rheostatic control do not show all the rheostatic losses that will be present in actual operation. The test does not include any periods of slow speed running prior to the stops nor does it include "inching" the car to make a landing while in actual service, these operations occur very frequently. If the motor is controlled over a wide range by armature series and shunt resistance as is the practise with gearless machines, the elevator will frequently consume more power while running at low speed than at high speed. For this reason the test values probably favor the rheostatic system more than the variable voltage system when compared with actual service conditions.

There seems to be quite a tendency among engineers when comparing variable voltage control with other systems to pay considerable attention to whether or not there will be a saving in power. As a matter of fact, in the majority of cases the other advantages of variable control that I have described, such as smoothness of operation, accuracy of control, saving in time, etc., are much more important considerations. I think Mr. Matson's analysis of the cost of operating elevators brings out quite clearly that the power consumed is a small item in the cost of operation.

L. D. Jones has questioned the results shown in Fig. 3 which show that the rate of building up of the generator fields is changed by the use of a damper winding, but the total time of building up is not materially affected. The inductance of the field circuit is made up of two factors, the self inductance of the main field winding and the mutual inductance of the short-circuited damper winding. If the inductance were actually constant, the field coil would have a true time constant and the

field flux would build up according to the well-known logarithmic law. However, the inductance is not constant but depends upon the permeability of the magnetic circuit and upon the amount of magnet leakage between the main winding and the damper winding. Now keeping in mind that the field poles are being worked at a lower point on the saturation curve when the field starts to build up than when it has built up to higher values, and also that the increasing magneto force of the main winding will cause a redistribution of the leakage flux, it is not unreasonable to expect a change in the shape of the curve when the damper winding is added. For other proportions of magnetic circuit and proportions of windings I would readily believe that different results would be obtained, as Mr. Jones states that he obtained from his tests. The results I have shown in Fig. 3 were obtained on test with an oscillograph.

The speed time curves obtained in Fig. 4 were taken by driving a magneto by the elevator motor and recording with a graphic voltmeter the voltages of the magneto. The voltage of the magneto was calibrated in terms of car speed with an ordinary tachometer. The method is not absolutely accurate and these inaccuracies no doubt account for the discrepancies in the curves that Mr. Jones mentions. I think Mr. Claytor's analysis of the curves explains why the motor speed does not follow exactly the building up of the generator voltage during the early part of the accelerating period. During the rest of the accelerating period and during retardation up to the point where the brake sets, I believe the speed and the generator voltage follow each other very closely.

Mr. Hansen has described an interesting system whereby he uses a voltage of rotation in an auxiliary machine to first oppose the impressed line voltage and then add to it to accelerate the main motor to a higher speed. By this means the energy which in a rheostatic system is dissipated in resistance is here stored in a flywheel and then returned as energy used in acceleration. It would seem that this system would be quite useful for constant speed work where acceleration and stopping make up the principal part of the cycle. It has the one drawback for elevator work, that speeds lower than full speed are not available. If the controller handle were left on a slow speed point the main motor would not run at this low speed except momentarily, because the energy input to the auxiliary motor would accelerate the flywheel and the main motor would accelerate due to the reduction in counter e. m. f. of the auxiliary motor. A slow speed which is constant and independent of load is one of the important requirements of elevator service and this requirement is one of the reasons why the variable voltage system has proved so successful in this field since it provides not only for smooth acceleration but also for speed control.

The discussion by Mr. Eames and by Mr. Bassett Jones illustrate the extent to which elevator engineers have analyzed the passenger himself when providing a conveyance for transporting him, in a vertical direction. I have no doubt that in the future more complete physiological as well as psychological tests will be made to determine the effect of acceleration upon the passenger, but I believe that a more exact solution of the problem depends equally as much upon the development of more accurate methods of testing the elevator to determine how closely it fulfills the required conditions.

A NOVEL ALTERNATING-CURRENT VOLTMETER[1]

(Wilson)

Philadelphia, Pa., February 6, 1924

R. S. Glasgow: The alternating-current voltmeter described by Mr. Wilson will be quite valuable in a large number of radio-frequency measurements. Particularly in the investigation of radio-frequency amplifier circuits is there a need of such an instrument. However, the type just described has too low a resistance to be employed in the majority of such circuits, as the radio-frequency current in the output circuit of the average vacuum tube amplifier is seldom more than a few milliamperes.

In order to overcome this objection to thermo-voltmeters I have employed a vacuum tube as an electrostatic voltmeter, using the circuit shown in Fig. 1, which is identical with a standard detector circuit. When a radio-frequency voltage, E, is applied to the terminals a b, the mean potential of the grid becomes more negative, causing a reduction in the average value of the plate current, I_p. The device may be calibrated by passing known radio-frequency currents through a known value of resistance, a typical calibration curve being shown in Fig. 2. Where considerable accuracy is desired a family of such curves should be obtained for various frequencies since the slope will vary slightly with the frequency of E. Since the resistance between the terminals a b is of the order of five to ten megohms, while the capacity can be reduced to less than 50 micromicro-farads, it is seen that the device can be bridged across almost any type of circuit without producing an appreciable change in the voltages and currents already present in the circuit. The terminal b should always be connected to that part of the circuit to be measured which is nearest ground potential.

By employing one of the several dry-cell types of tubes now available, the batteries, meters and tube may all be mounted n a shielded container and thus made portable. The accuracy of the device is of course lower than that of the volt-meter described by Mr. Wilson. Its calibration should be checked from time to time which is a common need with the majority of electrostatic voltmeters for low voltages. It will, however, enable the measurement of voltages across portions of a circuit wherein the amount of energy is too small to actuate the instrument described in Mr. Wilson's paper. The voltage range is limited only by the characteristics of the tube chosen and the plate voltage employed.

G. D. Robinson: It should be noticed that the indications of Mr. Wilson's meter depend upon the wave form as well as the effective voltage. A calibration made with one wave form may not hold for another.

Leon T. Wilson: The vacuum-tube voltmeter described by Mr. Glasgow in his discussion of my paper is not new. It has been in use in numerous laboratories for several years.

However Mr. Glasgow has rendered a service in bringing this useful device again to the attention of the electrical engineering profession.

The vacuum-tube voltmeter with its characteristic of a high input-impedance has a certain field of usefulness not covered by my voltmeter. On the other hand, as Mr. Glasgow mentions, it has the disadvantage of requiring frequent calibration. Also its calibration is dependent on the frequency, and therefore its calibration is materially affected by the wave shape of the voltage applied. In working with vacuum-tube voltmeters, it has been my experience that a great amount of care must be taken to insure reasonably accurate measurements. However, when such care is taken this type of voltmeter is a very useful instrument and well deserves the attention of engineers.

Mr. Robinson in his discussion states that "the indications of Mr. Wilson's meter depend upon the wave form as well as the effective voltage." The fact that the calibration of this voltmeter is practically independent of the frequency from low frequencies, say 25 cycles, to its upper limit, approximately 1,000,000 cycles, seems to me to be sufficient evidence to show that its indications, at least for all practical purposes, do *not* depend upon the wave form.

Since the presentation of my paper W. N. Goodwin, Jr. has kindly offered me the use of the results of his recent tests on the Weston model. The results follow:

The charging current, that is, that current taken by the voltmeter which leads the voltage by 90 degrees, was found to be one and one-half milliamperes for an applied e. m. f. of twenty volts and a frequency of one and one-half million cycles.

1. A. I. E. E. Journal, Vol. XLIII, May 1924, p. 446.

The error at full-scale deflection (20 volts) was found to be negligible at 600,000 cycles, 1/10 of one per cent at 1,000,000 cycles, and 4/10 of one per cent at 1,500,000 cycles.

SHAFT CURRENTS IN ELECTRIC MACHINES[1]

(Alger and Samson)

Philadelphia, Pa., February 6, 1924

W. F. Dawson: I can endorse one point which Mr. Alger made, namely that shaft currents are often associated with high saturation in the stationary armature cores of synchronous generators.

Some oscillograph records give the interesting information that the e. m. f. of shaft currents is greatly reduced as the generator voltage, and consequently the saturation of the armature core, is reduced.

My recollection is that we had approximately 5 volts potential at normal voltage and only 0.05 volts shaft potential with 50 per cent armature voltage.

We have built more than 2500 two-pole machines, of which less than 1 per cent have developed observable shaft currents, but on the other hand practically all of those that have given trouble should have been immune according to Mr. Alger's formula and the tabulation given as Fig. 15.

G. E. Luke: This is an interesting paper in that it describes a parasitic current or a loss which is peculiar in its effects. We are not interested in its effects on the performance or efficiency; we are interested in it solely due to its mechanical effects on the bearings. The bearing is a very simple part of the machine, but it is also a delicate part. A highly polished bearing will give a very low coefficient of friction. It is very important to reduce that to a low figure in high-speed machines. Any increase in the roughness of shaft will increase this coefficient and may cause bearing failure.

There is one point not mentioned by the authors and that is in connection with ball bearings or roller bearings. Of course, these bearings are ordinarily not used in large machines, but I have heard it said that the question of stray currents is a very serious limitation to their use in large machines because the ball bearing is especially sensitive to any imperfection on the surface of the bearing or race.

There is another point I would like to bring out, and that is: how did they measure the stray currents in the bearing, except by the usual method of putting a shunt around the bearing and using an ammeter, insulating the pedestal and shunting the insulation? Do the authors have any other methods which they use for measuring the currents in the bearing when they have an unsymmetrical magnetic field? The method of insulation in a pedestal machine is easy, but when we come to a bracket machine, it is not so easy on account of mechanical difficulties. Do they have any suggestions there as regards the elimination of the stray currents?

Chairman W. J. Foster: Last evening a designing engineer who has had a great deal of experience told me of a little telltale device that had been installed on some large generators of recent manufacture. It consisted in placing a low-voltage incandescent lamp across the insulation underneath the pedestal. The lamp stays lighted in varying degrees of intensity all the while, unless the insulation breaks down, and then it goes out. It is quite important that some such telltale device be installed, otherwise something may happen, such as I have seen on visiting plants, where after four or five years when a change in the management or a change in the operators has taken place, the insulation under the pedestal may be forgotten. In one case, iron steps had been placed on the base resting against the pedestal thus short-circuiting the insulation.

F. D. Newbury: As the authors of the paper bring out, the major cause of shaft currents has been known for a long time. I remember very distinctly a memorandum that Mr. Lamme circulated, I think it was in 1908, emphasizing the fact that the dissymmetry of the magnetic circuit was one of the principal causes of shaft current and cautioning against the use of certain combinations of poles and segments.

There is a possible inference from the paper that I hope will be avoided, that is the thought that insulation is, from this time on, to be frowned upon as an evidence of improper design. As Mr. Dawson brought out, there are cases in which results are difficult to predict, where, even with proper relations between poles and number of segments or between numbers of segments in the rotors and stators of induction motors, we do find shaft currents in spite of the proper relationship, and I think that all designers will continue to use bearing insulation as a precaution, even in those cases where shaft currents would not ordinarily be predicted.

A. M. Perry: On a trip through the Southeast about a year ago, I had the opportunity to observe a vertical-shaft water-wheel generator unit on which they had had considerable trouble with the bearings melting. They didn't look into the cause of the trouble, but they did put slip-rings on the lower end and the upper end of the shaft and connected them to a ground so that there was a very low-resistance connection between the shaft and what would correspond to the pedestal of the bearings. They told me that this method eliminated the trouble entirely.

W. J. Foster: In line with Mr. Newbury's remarks and Mr. Dawson's, that there may be cases of shaft currents where they would not be expected in accordance with the theory on which this paper is based, I would like to have the authors, in closing, make a statement as to whether they rule out all other causes.

Personally, from my own experience, I consider mechanical dissymmetry at the two ends of the shaft in certain cases as responsible,—for example, in a 12-pole vertical machine with a 6-arm bracket at the top and no corresponding bracket underneath; where shaft currents were much in evidence, it seemed to be perfectly natural to ascribe the reason to the stray flux cutting the arms synchron-

As I understand the paper, it does not necessarily shut out other sources of trouble besides the particular relations of the segments in the core.

E. A. Smith (by letter): Referring to the paper of Messrs. Alger and Sampson, I have noticed that a considerable number of the tests mentioned, have been treated in detail in some of the foreign societies' publications in which a special study is being undertaken to eliminate stray shaft currents. Particularly in Germany the electrical manufacturing concerns are trying a method of insulating the bearing pedestals from the base of the machines. They have so far not been able to insulate the end shield bearings but they are employing a non-magnetic babbit lining and non-magnetic pedestal.

No doubt in due time, by installing these non-magnetic babbit linings and by splitting the yokes as set forth in Messrs. Alger and Sampson's paper these stray shaft currents will be very much eliminated.

Most of this trouble has been found in synchronous and induction machines, where, uneven air gaps were found to exist, but in a few cases where new machines were installed, the trouble was due entirely to the flux traveling along the shaft to the bearings.

Tests were made in these cases and as far as could be observed, the only remedy would be for manufacturing concerns to investigate these conditions thoroughly and eliminate them as much as possible.

P. L. Alger: We believe that certain irregularities in the construction of the core are inevitable and therefore that any machine will have some shaft current, even though it is very well constructed, if you measure it with a delicate enough instrument. Therefore, it is not desirable to remove the insulation from very large and important machines, even though it

1. A. I. E. E. Journal, Vol. XLIII, December, p. 1325.

may be believed that they will have no shaft currents. But we do believe that a great many machines do not need any insulation, although they are now provided with it as a matter of standard practice; and also we believe that certain machines which now, because of their classification, have no insulation, would be better provided with it.

I agree with Mr. Foster and Mr. Newbury, that it would be very undesirable to provoke a series of troubles with shaft currents by removing it, but I do think that operating men may profitably measure the shaft voltage in machines they have operating, and in those cases where it is not a vitally important, large, machine and where they find no shaft current by tests, they may with impunity take less care of the insulation. If enough experience is accumulated we may be able to make some progress in avoiding the troubles we now have.

The question was asked how we measured the shaft current. We do that ordinarily by merely placing an ammeter between the two ends of the shaft. In that way we measure a current in parallel with the path through the bearings. But we believe that when the oil film is still intact and not damaged by any cause, that the current flowing through the bearings themselves is negligible in comparison with that which will flow through a short-circuit path around the ends of the shaft. In those cases where we have had to insulate end-shield machines, we have done it by placing a band of insulation around the bearing itself, inside the bearing housing. In that way it is possible to make a satisfactory insulation, but it is very inconvenient to do, and if the bearing is removed it must be very carefully handled, so we do not wish to do that when it is possible to avoid it.

This question of shaft currents is particularly important in machines built for ship propulsion, where space is valuable and where the presence of salt water and of various other pieces of apparatus makes it very difficult to insulate, and also where end shields are almost always used to save space. We therefore believe it particularly desirable to apply this theory to machines intended for ship propulsion.

I will call your attention to the fact that in this paper as printed, the figures have been misarranged. Fig. 7 should be Fig. 8; Fig. 9 should be Fig. 7 and Fig. 8 should be Fig. 9. Furthermore, the true Fig. 9; that is, the one that is called Fig. 8 in the paper, has been turned through 90 degrees to the left, so that the top is now at the lefthand side. These figures are so much alike that it is hard to follow through the discussion without having the right titles.

POWER PLANT AUXILIARIES AND THEIR RELATION TO HEAT BALANCE[1]

(PENNIMAN)

PHILADELPHIA, PA., FEBRUARY 6, 1924

H. W. Brooks (by letter): Mr. Penniman's paper is of intense interest to many designers now working on *new* plant construction. There is, however, a vast field for application for heat-balancing devices in plants designed prior to the last three to five years as there are undoubtedly enormous losses taking place in many of these older plants owing to lack of proper heat balance. In private consulting practise last year the writer encountered a very interesting problem of this character in the plant of the Chicago, Aurora and Elgin Railroad Co. at Batavia, Ill., where a dual-drive exciter set of 300 kw. capacity was finally designed in cooperation with the manufacturer. The steam end consisted of a 200 lb. pressure, 150-deg. superheat, non-condensing, direct-connected turbine of the impulse type, while the electric drive end consisted of a three-phase, 25-cycle, 2300-volt, phase-wound, induction motor, both machines being direct-connected to the 300 kw. generator mounted between them and functioning at 750 rev. per min.

It will be noted from the following functions performed by this set that it covers all of the merits of the basic Clarke patents on dual-drive heat-balancer sets and in addition covers automatically a number of new functions not heretofore performed automatically, and by so doing eliminates attention on the electrical end of the set previously required by either the operator on the engine-room floor or the switchboard operator. The complete functions of the set follow:

1. In case of failure of voltage on main a-c. generators motor cuts out and d-c. load is taken by the turbine.
2. In case of failure of frequency on main a-c. generators motor cuts out and d-c. load is carried by turbine.
3. In case motor is tripped out on account of under voltage it is restored to the line upon resumption of proper voltage.
4. In case motor is tripped out on account of low frequency it is restored to the line upon resumption of proper voltage.
5. In case of reversal of a-c. power caused by the induction motor, driven as an asynchronous generator, motor is tripped out and entire load carried by turbine and after turbine speed has been so reduced as to restore normal direction of flow on the alternating-current line motor is restored to the line.
6. In case of accident to the a-c. motor, motor trips and latches out and load is carried by turbine until such time as motor is repaired.
7. The various relays such as the frequency relay, selective watt relay, etc., are arranged with suitable interlockers in connection with the low-voltage relay equipment and the starting equipment so that each will operate independently.
8. Motor is capable of being thrown on the line either from zero speed or from full speed, which latter condition occurs when the set is started from the turbine end.
9. On reversal of d-c. power the d-c. breaker is open but need not necessarily be recloseable automatically upon restoration of normal direction of power flow. Should this occur, however, the steam and control must trip automatically to prevent running away of the machine in case low feed-water temperature should cause high-pressure valve at that time to be open.
10. Secondary motor control is entirely automatic, functioning at all times as the primary or breaker functions.
11. In general, in the event of any accident to the motor the turbine picks up the load and carries any part or all of it, and similarly in the event of an accident to the turbine the the motor must instantly pick up the load and carry any part or all of it. The combination is so arranged that the turbine will carry variable loads automatically normally, dependent upon the amount of steam necessary to pass through the turbine to keep the feed-water temperature up to 212 deg., the motor automatically pulling the balance. Load is automatically shifted from one method of drive to the other in such manner that the regulation of the direct current supplied will not be visibly affected.
12. Normally the turbine exhaust is automatically regulated in such manner as to pass only sufficient steam through the turbine to supply necessary exhaust steam heat to the incoming feed water so that no steam is lost by exhausting it to the atmosphere, the remaining load being carried by the motor.
13. Emergency features, however, are provided on the turbine as above mentioned so that if for any reason the electric supply to the motor should be cut off, the turbine would automatically open its valves and continue to drive the exciter without any interruption in the supply of excitation, even if by so doing considerably more exhaust steam would be supplied than would be necessary to raise the feed water to 212 deg., which means that in such abnormal circumstance exhaust steam would be wasted into the atmosphere.

Frank G. Boyce (by letter): I agree with the author that it is desirable to approach as near as possible all-electric drive for auxiliaries. However, I feel that it is good practise to have at least one boiler feed pump in the plant which is steam-driven, the thought in this being that continuous supply of water to the boilers is absolutely necessary in modern plants where the storage capacity in the boilers is reduced to a minimum and with the

1. A. I. E. E. JOURNAL, Vol. XLIII, February, 1924, p. 118.

tendency towards higher ratings. It seems both economical and desirable to bleed the main turbines for stage heating of the feed water and preheating the combustion air for stokers.

I would suggest that instead of a direct-current generator being used mounted on the end of the main turbine shaft for source of auxiliary power, an alternating-current generator be used for this purpose and that the shaft be further extended to provide space for an exciter. The reasons why I would suggest this instead of the scheme suggested by the author are as follows:

1st, I am rather inclined to believe that the reliability of the unit would be somewhat reduced if the excitation were taken from the same generator which supplied power to the auxiliaries around the plant, so that troubles in the various motors and equipment would be transmitted to the field circuit and rotor, which might cause interruptions to service from the main unit.

2nd, I would suggest that the boiler feed pumps be driven by constant-speed alternating-current motors, except one emergency pump which should be steam-driven. This arrangement works very satisfactorily and instead of maintaining a constant differential pressure between the feed water and the boiler pressure, a constant feed-water pressure is held somewhat above the normal steam pressure. This will operate perfectly satisfactorily with modern types of boiler feed regulators. This, therefore, eliminates the necessity for variable-speed direct current motors on boiler feed pumps.

Of course, variable-speed drive for stokers is necessary and this could be obtained very nicely by the use of two rotary converters of sufficient capacity to furnish power for only the stoker motors. This makes a rather economical installation. However, it is also possible to obtain stokers driven by hydraulic pistons which eliminates the necessity for direct-current variable speed on the stoker drive.

The only drive now for which direct-current variable-speed motors seems necessary is condenser pumps. I suggest that a very economical arrangement is two pumps of different sizes installed on the condenser, one pump to be used at light load, a larger one at medium load, and both pumps to be used in case of very warm circulating water or heavy overloads.

I believe that the installation as mentioned, eliminating the direct-current variable-speed motor drives, will give as good satisfaction, will be more reliable, and the cost per kilowatt of investment will be less.

A. L. Penniman, Jr.: The discussion, by letter, of Frank G. Boyce admits the desirability of all-electric drive. The writer agrees that there should always be one boiler feed pump in a plant which is steam driven. This should be for purely emergency purposes and should take its suction from the service water supply. The turbine driving this pump may properly be allowed to exhaust to the atmosphere, as it will run only on very infrequent occasions.

Mr. Boyce's suggestion that an a-c. generator be direct connected to the main turbine shaft for auxiliary power is entirely feasible. It might be somewhat cheaper than a d-c. generator. A-c. motor drive for auxiliaries might also be slightly cheaper than d-c. motors. The combined efficiency of the generator and motors would, of course, be lower where alternating current is used with the motors running at reduced speed. In the writer's opinion the alternating current would be somewhat more reliable, due to the elimination of commutators and due to the fact that a short circuit could be much more readily cleared up than if direct current be used.

Variable speed motors driving the boiler feed pump are advisable though not necessary. On the closed system outlined in the paper the duty can be so divided between the hot-well pump and the boiler feed pump that the bulk of the work is done by the hot-well pump, leaving a relatively small amount for the boiler feed pump. The hot-well pump may then be driven at constant speed, the desired pressure being maintained by varying the speed of the boiler feed pump motor. It would seem that this motor need be capable of carrying only 25 per cent of the power desired by the two pumps when both are operating at rated capacity.

The proof also includes a statement from the JOURNAL of of February, 1924, having to do with the so-called Clarke patents on dual-drive exciter sets in which, what are apparently the claims of the Clarke patent are stated as functions performed when the house generator is driven from the main turbine shaft. This, of course, is not a matter of fact, as the writer cannot conceive how, under normal conditions, the main generator can be driven by the main turbine and in turn supply the power for driving the auxiliary generator which is hooked on the same shaft. There can be no question that the auxiliary generator is driven by the main turbine. It is not called on to perform any of the functions performed by the dual-drive exciter.

The writer's scheme permits of taking the maximum advantage of stage bleeding from the main unit, and at the same time obtain a reliable source of power for auxiliaries by driving the auxiliary generator by the main turbine. Whether the generator supplies alternating current or direct current is largely a matter of personal preference of the designer and balancing the increase in first cost of direct current against its economy in operation.

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TELEGRAPHY AND TELEPHONY COMMITTEE

To the Board of Directors:

In this report we are giving a brief summary of the advances which have been made or which have come into prominence in the communication art during the past year. The papers which have been presented under the auspices of this committee have, in general, been a record of such advances, and they are mentioned under the appropriate headings in the report.

TELEPHONE EQUIPMENT

Transformers perform so many and such valuable functions in telephone circuits that the paper on "Telephone Transformers," read at the February Convention, covers a field of the very highest importance. Some interesting special requirements in telephone transformers have been introduced by the comparatively high impedance of many vacuum tube circuits.

One phase of the very important subject of machine switching was presented to the Institute during the year in a paper on "The Economic Development of a Step-by-Step Automatic Telephone Equipment."

TELEPHONE TRANSMISSION

A "telephone transmission unit," differing from the commonly used "mile of standard cable," has been

adopted for general use by the companies of the Bell System. A paper entitled "The Transmission Unit and Telephone Transmission Reference Systems," to be presented at the June Convention of the Institute describes the unit and the reasons for adopting it.

As telephone circuits, particularly long distance circuits, are necessarily elaborate and complicated, it is very important that convenient and rapid methods be available for checking their transmission efficiency at frequent intervals. A February Convention paper on "Measuring Methods for Maintaining the Transmission Efficiency of Telephone Circuits" discusses this important problem.

In all engineering of communication circuits and apparatus it is important to know accurately the characteristics of the currents and voltages which are being carried by the circuits, whether these be the signaling currents themselves, or interfering currents. A very convenient tool for analyzing currents into their component frequencies was described in a February Convention paper on "An Electrical Frequency Analyzer."

Two papers giving interesting and important discussions of long distance telephone transmission were given at the Pacific Coast Convention under the titles "Telephone Transmission over Long Distances" and "Applications of Long Distance Telephony on the Pacific Coast."

Outside Plant Practises

The Western Union Telegraph Company are employing, after an investigation of about three years, a method of treating existing pole line timber for the purpose of prolonging its life. They consider this method so promising that the apparatus for its application has been well standardized, and the practise of treating poles in this manner extensively adopted during the past year.

In this treatment the earth is first excavated from around the pole to a depth of about 18 in., decayed matter thoroughly cleaned off, and where practicable the pole allowed to air-dry for a few days. The section to be treated is then heavily charred by means of a portable kerosene burner, and while the pole is still hot, creosote that has been previously heated to a temperature between 180 deg. to 212 deg. fahr., applied by means of a high-pressure spray until the temperature of the pole has been lowered to the temperature of the oil, and all vaporization ceased.

The heat of the charring flame thoroughly sterilizes the timber and destroys any existing decay fungi, bacteria or borers; dries the wood and drives out all moisture; opens up checks and cracks to at least as great an extent as will probably occur in ultimate seasoning; heats the wood to a temperature higher than that of the oil so its subsequent cooling during the spraying process will actually contract the air in the cells and draw in the oil; and changes the thin, hard, outer layer of wood into a porous sponge of charcoal which acts as a reservoir to store up a considerable quantity of free oil that will afterwards gradually soak into the underlying layers of wood.

Telegraphy

The development of long telephone cables of 19 and 16 gage, capable of operating for distances of 1000 mi. and upward, has also led to the development of telegraph systems capable of operating through these cables. Two telegraph systems especially designed for the purpose are in commercial operation over such cables. It is expected that papers describing these systems will be presented to the Institute during the coming year.

In telegraphy there are certain definite relationships between the possible speed of operation over a circuit, the frequency range available for the circuit, the alphabet used, and other factors. Some of the fundamentals of these relations were brought out in a paper read at the February Convention, entitled "Certain Factors Affecting Telegraph Speed."

Submarine Telegraphy

The Western Union Telegraph Company expects to complete the laying during 1924 of a radically new type of ocean cable developed by the Western Electric Company. The cable to be laid will extend from New York to the Azores, there to connect to points on continental Europe. It is being manufactured by the Telegraph Construction and Maintenance Co. of London, England. The manufacture of this cable involves the use of a new material and new processes. In order to have a practical confirmation of the results which laboratory tests and theory indicated should be obtained, the engineers of the two companies made the unprecedented experiment of laying a temporary trial length of 120 miles of this cable in a loop from the island of Bermuda, and carried out comprehensive tests over it.

The essential difference between this cable and cables previously laid lies in the provision of a thin layer of "permalloy" placed in the cable between the copper conductor and the gutta percha insulation. "Permalloy" is a recent development in magnetic materials made by the Western Electric Company, consisting of a nickel-iron alloy with about 80 per cent nickel. At small field strengths its permeability is many times greater than that of any material hitherto known.

The layer of permalloy is obtained by putting the alloy in tape form and wrapping it around the conductor. This increases the self-inductance of the conductor per mile—that is, the cable is "loaded." This reduces the attenuation and distortion of telegraphic signals and permits transmission at higher speeds over the cable. The new cable is no heavier in weight or larger in outside diameter than any of the cables recently laid by the Western Union Company, yet its message capacity, as shown by the recent tests, is

expected to be fully three times as high as cable of the old type of similar weight and length.

With cable of this efficiency it may become practicable and economical to make considerable increases in the lengths of sections between terminals, thereby cutting down the number of stations where meassges are repeated with obvious operating advantages.

Radio

The great public interest in radio telephone broadcasting has continued to grow during the year, and such broadcasting is already established as a very important facility in our modern civilization. Much remains to be done, however, in improving the quality of the transmission received, and in overcoming interference. Two papers of interest, particularly in connection with these matters, were presented at the February Convention, one on "High Quality Transmission and Reproduction of Speech and Music," and the other on "The Function and Design of Horns for Loud Speakers."

The rapid development of radio broadcasting left the part of the National Electric Code covering the installation of radio sets and antennae in an unsatisfactory form. This has now been taken care of in the new code adopted at a convention of the National Fire Prevention Association in Atlantic City, and going into effect from December, 1923. Since the total of radio installations is now in the millions, the importance of this work is evidently very great.

In last year's report there were recorded tests of radio telephone transmission from America to England carried out in co-operation by the American Telephone and Telegraph Company and the Radio Corporation of America. Following this work, the British Post Office appointed a committee to consider transoceanic telephony, and this committee has now recommended that the British Post Office install at its new Rubgy radio station a 200-kw. transmitter of a type similar to that which was used by the American engineers in their transmission to Europe. If the committee's recommendations are followed, it will result in a station in England which can talk back to America, thus permitting two-way tests between the two countries.

Tests of transmission from America to Europe have been carried out at practically weekly intervals throughout the year, and this data, together with the data which will be made possible by two-way tests, will determine the practicability of a United States to London transoceanic telephone service. Under favorable weather conditions in winter, it is the expectation that telephone subscribers in the United States and in London can be connected so they can talk together as over ordinary telephone circuits. The difficulty of giving a continuous service, however, can be appreciated from the fact that in spite of the long wave lengths used, the amount of power necessary to give satisfactory speech in London at one time may be as much as 10,000 times as great as that required a few hours earlier.

An outstanding development in radio has been the use of short wave lengths of 100 meters and less for transmitting material for rebroadcasting and for other purposes. Under some conditions these shorter wave lengths appear to travel with less loss and less interference than do the wave lengths ordinarily used in radio broadcasting. Under some conditions, however, the short waves appear to involve rapid fluctuations which are not yet completely analyzed and understood. There is not yet sufficient data available to determine just how great the practical value of these short waves may become.

A paper on "Radio Telephone Signaling—Low Frequency System" read at the February Convention describes important developments which have been made in radio calling systems to permit any one of a considerable number of radio stations to be "rung up" without interference with each other, and with a high degree of reliability.

Many forms of selective circuits are in use, or have been proposed for reducing the effects on radio transmission of static interference. A theoretical discussion of the possibilities and limitations of such circuits will be given at the June Convention in a paper entitled "Selective Circuits and Static Interference."

Telephone, Telegrpah and Radio Terminology

The Bureau of Standards has been carrying on active work on the question of telephone, telegraph and radio terminology, which they believe will lead to much more satisfactory definitions of the terms used in the communication art. One feature of this work is that key terms are first defined, such as "telephone," "telephone station," "telephone line," "central office," etc., and then related and associated terms are defined on the basis of their relationship to the key turns. Illustrative examples of definitions made up along these lines have been prepared, and it is expected that a paper on this whole subject will be available for submission to the Institute during the coming year.

Military Signaling

The potential value of radio signals as an aid to the navigation of aircraft at night and in fogs has long been recognized, but the application has been delayed largely because special receiving equipment of considerable bulk and weight seemed to be necessary in the air where both space and lifting power are limited. The Signal Corps of the Army has sought a solution of the problem which might keep all the special equipment on the ground and has during the past year built an experimental station which has given most satisfactory results. The system in brief, consists of a radio transmitter at a ground station which is coupled to two crossed loop antennas alternately in such a way that double dashes sent by an automatic transmitter are received with equal strength in one vertical plane only through the station. This plane may be given any direction by adjustment of the special coupling

device, or it may be made to rotate continuously at the rate of one complete revolution per minute. The former is desirable for aircraft flying over fixed routes. In this case the pilot simply steers a course which keeps the two received signals of equal intensity. The rotating equi-signal plane is better adopted for military operations of aircraft from their base. In this case, a special timing signal is automatically sent out from a non-directional antenna at the instant the equi-signal plane extends due north, and the double dashes follow that timing signal at 10-sec. intervals. A pilot hearing the timing signal, simply counts the signal pairs heard until he hears a pair of equal intensity. If that equality comes in the seventh pair following the timing signal it is evidence that the line joining his position and the transmitting station makes an angle of 7×10 deg. = 70 deg. with the North-South line through that station. The direction of rotation of the equi-signal plane is determined by the direction of rotation of the coupling device and is necessarily made known to pilots in advance. No special equipment of any kind is used in the air, the ordinary radio receiving equipment serving for both communication and position finding.

During the past year, the Army has put into service two radio stations, using water-cooled vacuum tubes of 5 and 10-kw. rating, and delivering 10-kw. to the antenna. The transmitters are remotely controlled from receiving stations where both automatic transmission and recorded reception are employed at speeds up to 75 words per minute. These two stations, as well as several others of lower output, are daily handling practically the whole of the War Department telegraph traffic, as well as traffic for several other government departments.

The Signal Corps of the Army reports that it is also actively developing an a-c. system for submarine cable telegraphy, and a uniform code for all forms of transmission, *i. e.* wire, cable and radio. Certain of these developments will be tried out shortly on the Alaskan cable system, and it is hoped that a paper on these results will be made available for the A. I. E. E.

Carrier Telephone Operation over Power Lines

A number of different systems has been developed for permitting the superposition of a telephone channel on an operating power line by employing carrier current methods. Four papers have been presented to the Institute on this subject during the year, three at the California Convention, entitled "Recent Developments in Carrier-Current Communication," "Carrier-Current Telephony on the High Voltage Transmission Lines of the Great Western Power Company" and "Some Experiences with a 202-Mile Carrier-Current Telephone," and one at the Birmingham Convention entitled "Carrier Telephony on Power Lines."

Supervisory Signaling Systems for Power Circuits

Several supervisory signaling systems for the control and indication of remote power equipment in power distribution systems have appeared during the year. With these systems an operator at a central point may know continuously the condition of operating units at one or more distant stations which may be unattended and may control these units as he may desire.

Audiometers

Instruments for measuring the acuity and quality of hearing have been developed. In these instruments a thermionic tube oscillator is arranged to produce pure tones which may be varied in pitch and intensity throughout the range of auditory sensation. The determination of the amount of tone required for hearing as the pitch is varied over the range, gives data of great importance in studying the condition of the hearing of those who are partially deaf.

Transmission of Pictures over Telephone Lines

A demonstration was recently given to the press of the capabilities of a new system for electrically transmitting pictures over long distance telephone lines developed by the engineers of the Bell Telephone System. The sending apparatus was located in Cleveland, Ohio, and the receiving apparatus in New York City, a long distance telephone line connecting these points.

In this system a photoelectric cell, responding to variations in intensity of a beam of light shining in turn through successive elements of the picture to be transmitted, is employed to modulate an alternating current. This modulated alternating current transmits the picture over the telephone line. At the receiving end this alternating current controls a beam of light by means of a device called a "light valve" so that successive elements of a sensitized film are exposed in accordance with the lights and shades in the original picture. The picture to be transmitted and the sensitized film at the receiving end are mounted upon cylinders, these being rotated in synchronism by means of a low-frequency alternating current which passes over the same telephone circuit which transmits the picture current.

The system was shown to be adaptable to the rendering of commercial service. It is possible to transmit not only photographs suitable for reproduction in a newspaper, but also line drawings, printing, and handwriting.

It is stated that the extent to which the system will be used in conjunction with long distance telephone lines will depend upon the demand which arises for this type of service. The system is also applicable to radio transmission of pictures when atmospheric conditions are such that steadiness of transmission and freedom from interference can be assured.

The Committee is especially indebted to its following members for their activities in obtaining material for this report: E. H. Colpitts, H. W. Drake, R. D. Parker, F. A. Raymond, Edgar Russel, F. A. Wolff.

O. B. Blackwell, *Chairman.*

RESEARCH COMMITTEE

To the Board of Directors:

PART I

Activity in the field of electrical research has been very pronounced and has covered a very wide range during the past year. A number of results of outstanding importance may be recorded, although it does not appear possible to single out any one of them as being pre-eminent over the others.

In the field of molecular physics and the constitution of matter notable progress has been made, resulting in greater certainty as to the nature of the structure of the atom, particularly with reference to the relations of electron orbits, the quantum theory or radiation, and the functions of the electron structure as determining chemical affinities and reactions. Also from the physical laboratories, we have important new data on gaseous conduction at low pressures, and on the production and behavior of electronic emission in high vacuua. The application of these new data has led to great improvements in the construction of vacuum tubes, particularly in the directions of higher power and greater efficiency.

Special mention should be made of the intensive studies which have been devoted to the field of magnetism. Noteworthy papers have been printed on the relation of the magnetic and mechanical properties of steel. Increased knowledge is available as to alloys having high permeability at low flux densities. An especially noteworthy contribution has been made on the importance of carbon, even in the smallest quantities, on the magnetic properties of the iron-silicon alloys and the exact nature of its influence.

There has been unusual activity in the study of the properties of high-voltage insulation. These studies have taken the form of a continuation of tests under the conditions of practise, as for example, in the study of high-voltage cables, and also of laboratory investigation aiming at a better understanding of the underlying processes. Studies in this field, either completed or under way, cover the following variety of topics: The insulating properties of glass as affected by moisture, the pyro-electric theory of breakdown with special reference to paper insulation, internal ionization and its influence on the life of insulation, dielectric absorption in builtup insulation, the importance and exclusion of moisture in builtup insulation, the transmission and dissipation of heat in insulation and reviews of theories of insulation.

In the high-voltage field a number of observations on 220-kv. lines has resulted in further knowledge of the conditions to be met in this important new field. Unusually high values in voltage in both laboratories and on power lines have been the means for further study with particular reference to the question of line insulation. These studies are resulting in a steady extension of our knowledge and in the improvement in the methods for handling higher values of voltage for transmission.

Numerous other problems have been attacked, among which may be mentioned the study of net works of conductors for transmission and distribution, the performance of storage batteries with special reference to impurities in electrolytes, the standardization and accurate measurement of radio frequencies, and the properties of electrolytic rectifiers.

PART II

The committee has had before it as its principal object a thorough review and digest of the literature under the eight headings of the Problem of Insulation, as published in the JOURNAL of the Institute for June, 1923, and which was a joint report of the Committee on Research of the A. I. E. E., and the Committee on Electrical Insulation of the Division of Engineering, National Research Council. The committee has addressed itself first to the securing of volunteers for carrying out this examination of the literature, and to this end has published appeals at various times in several journals, and has addressed letters to a large number of authorities and workers in the field of insulation, always requesting cooperation and assistance.

While the number of volunteers for the work of the examination of the literature has been disappointingly small, a beginning has nevertheless been made in connection with the principle sections of our report. A chairman of a sub-committee has been appointed in connection with each of the sections, and the assignments are as given in the following list:

I Reviews and Compendia of Work Already Done Subdivided among the following sections

II Nature of Dielectric Absorption
J. B. Whitehead, Chairman, C. A. Adams, Michel G. Malti, H. H. Race

III Phase Difference in Dielectrics
Delafield DuBois, Chairman, LeRoy Clark

IV Electric Strength
W. A. Del Mar, Chairman, F. W. Peek, Jr., G. B. Shanklin

V Dielectric Constant
T. S. Taylor, Chairman

VI Restivity
H. L. Curtis, Chairman

VII Flashover Voltage
F. W. Peek, Jr., Chairman,
R. H. Marvin

VIII Theories
V. Karapetoff, Chairman
J. B. Whitehead.

A standard form for recording the results of the examination of a single paper has been prepared and forwarded to all workers. The use of this form should not only facilitate collection of data and the preparation of individual reports, but it is hoped that it will also assist greatly in the collection and coordination of all the investigations on particular topics.

Reports from the several sub-chairmen indicate that substantial progress has been made, particularly under headings, II, IV, VI and VII. So far as the actual examination of the literature is concerned, the particular value of this work, will be found in the summaries and conclusions under the special headings, which the committee hopes will include statements as to the present problem under these headings with suggestions for the most profitable line of experimental attack.

The committee held a meeting at the recent Philadelphia Convention of the A. I. E. E. at which nine members were present, and at which the various topics in connection with the program were discussed. Of particular interest was the report of Professor Karapetoff of Cornell University of a grant of money from the Heckscher Foundation for experimental work in the field of insulation, and that this committee had rendered him material assistance in the securing of this grant. The committee endorsed the general outline of the work proposed by Professor Karapetoff.

While it cannot be said that the work of the committee is progressing rapidly, it must be remembered that the character of the work now before it is of such a nature as to require time and sustained effort. Surveys in the field of insulation can only be made by experienced and competent men, and under our present plan we are relying entirely on the voluntary efforts of a comparatively small number. All of them are busy men, and with them the work of the committee must necessarily take a subordinate place. The committee is endeavoring to point out that the examination of this literature is a research work of first importance, and that in each case it will constitute a valuable publication. Nevertheless the present method of procedure undoubtedly means that the progress made will be very slow. Apparently it can only be greatly accelerated by the securing of the full time or perhaps the half time of two or three competent men. Obviously, for this purpose financial support is necessary. The work which the committee has outlined cannot properly be done by graduate students or inexperienced men. The committee, therefore, recommends that the Institute consider the advisability of the raising of a small fund for the purpose mentioned, or possibly in some other way secure the more extended services of men competent in this advanced field.

J. B. WHITEHEAD, *Chairman.*

INSTRUMENTS AND MEASUREMENTS COMMITTEE

To the Board of Directors:

The Instruments and Measurements Committee submits the following report, giving briefly a summary of its activities during the past year.

At the Mid-Winter Convention held at Philadelphia, February 4th to 8th, one session was assigned to the committee. The following papers were presented.

1. *Method of Testing Current Transformers,* by F. B. Silsbee. This paper described eleven methods which might be used and gives the advantages and disadvantages of each, together with results which might be expected.

2. *Recent Developments in Kilovolt-Ampere Metering,* by B. H. Smith and A. R. Rutter.

This paper described two suggested types of commercial kilovolt-ampere meters.

3. *Automatic Transmission of Power Readings,* by B. H. Smith and R. T. Pierce.

This paper described seven methods by which meter and instrument readings may be transmitted to distant points and results which might be expected from each.

4. *Quadrant Electrometer for Measurement of Dielectric Loss,* by D. M. Simons and W. S. Brown.

This paper described a new zero method of using an electrometer for testing cables.

This group of papers was well received and an interesting discussion followed.

Standardization of Electrical Measuring Instruments, by H. B. Brooks.

At the annual convention in June, 1923, as mentioned in our previous report, the first draft of specifications for standardization of instruments was presented. The committee has done nothing since that time, preferring to wait for the results and comments covering this first section before going ahead with additional sections. It is expected, however, that in the near future this committee will again actively take up this work with a view of ultimately developing a complete set of specifications on instruments.

Developments. The principal development during the year is probably the announcement of a commercial type of kilovolt-ampere-hour meter. The Westinghouse Company announces that it will have a commercial type meter available during the Summer of 1924. The Committee also understands that the General Electric Company and the Sangamo Company will have models available in the near future.

The tendency of the art toward the use of small indicating instruments as mentioned in last year's report seems to be continuing and we would expect larger demands for the smaller instruments in the future.

A number of operating companies have installed systems of remote metering and totalizing of power readings. The benefits derived by having at one central point the readings of all power stations is greatly appreciated by system operators and executives. It is anticipated that considerable progress along these lines will be seen in the immediate future.

Bottom-connected meters in polyphase and direct current types of meters are appearing on the market and finding considerable favor. The General Electric Company has announced a new bottom connected d-c.

meter and the Sangamo Company a bottom connected polyphase meter.

The report of I. B. Smith, summarizing the activities abroad in the instrument field is attached. This gives in a very complete and convenient form the summary of the work being carried on in foreign fields and is presented for the convenience of our members and for the sake of its historical value.

G. A. SAWIN, *Chairman.*

This report concludes with notes on foreign activities in this line.

COMMITTEE ON MINES

To the Board of Directors:

The Committee on Mines has very little to report this year. There has been but one session held, at which papers pertaining to mine electrification were presented —namely, at the Birmingham Meeting. At this meeting a partial mining session was held, and three papers were presented on mining subjects. One of these was by L. C. Ilsley, Electrical Engineer of the Bureau of Mines, and was entitled, "Electrical Safety in Coal Mines." C. E. H. Von Sothen of the Industrial Engineering Department of the General Electric Company presented a paper on, "Automatic Sub-Stations for Mines;" and F. R. Grant and the writer presented a paper on "Tests on Mine Hoist Control," describing the operation of a large Ward Leonard hoisting equipment. Mr. Grant is also of the Industrial Engineering Department.

There has been no meeting of the committee this year, as the members are so widely scattered throughout the country and there have been no matters of sufficient importance to warrant calling them together.

No real constructive work has been undertaken by the committee, as there does not seem to be any field for such work at this time. The most urgent requirement in the mining field today, as far as electrification is concerned, seems to be the want and need of a satisfactory code for the safe installation of electrical apparatus underground, and this has been prepared by the American Mining Congress and the Bureau of Mines. This code is at present on the way to the Engineering Standards Committee for final approval. The majority of the members of your committee have been in touch with this work, and this field is very satisfactorily covered.

As to suggestions for future procedure, I feel the only way we can stimulate general interest in the work, of this committee, and possibly within the committee itself, will be by the holding of a joint session with some one of the important mining societies, and I would strongly recommend that such a joint session be considered. I believe that if this was put through it would be possible to secure quite a number of interesting papers on engineering subjects pertaining to electrification of mines; but electrical engineers intimately connected with mining work, I am afraid, do not feel that the A. I. E. E. is sufficiently interested in their work to warrant their presenting papers.

F. L. STONE, *Chairman.*

TRACTION AND TRANSPORTATION COMMITTEE

To the Board of Directors:

Just before the close of the last administrative year, a special committee was appointed to consider and report to the Board of Directors:

1. As to the desirability of continuing the Traction and Transportation Committee.

2. If the committee is to be continued, as to the character of the work which should be expected of it.

3. As to a specific program recommended for work of the committee for the ensuing year.

The committee reported on October 6 and recommended, in brief, substantially as follows:

1. That the Institute should have a technical committee to cover, broadly, the field of transportation.

2. That the most important function of such a technical committee would consist in guiding the activities of the Institute so that authoritative papers could be secured, bearing on the most important topics. Various subjects were suggested under this heading.

3. For the ensuing year, the committee recommended that the plan which the Meetings and Papers Committee had initiated for having a Railway Session at the Midwinter Convention in Philadelphia be carried out; that this meeting be devoted exclusively to the production of papers by railway executives and operating men, if suitable papers could be secured.

The report was adopted by the Board and the present committee was appointed early in November with instructions to follow out the plans suggested. The recommendations of the committee concerning the Midwinter Convention were carried out. Two Transportation Sessions were held on February 5, one in the afternoon, the other in the evening. The latter was one of the largest ever staged by the Institute; it was held in the Metropolitan Opera House in Philadelphia and the proceedings were broadcast all over the country by radio. Five addresses by prominent railway and other executives were of a high grade and much appreciated. They were of a general character, of interest to everyone and as such they should be preserved.

The afternoon session was notable from the fact that the railway problem was discussed largely by railway operating men and brought out a good many interesting side lights. The committee undertook to catch a vision of the future of rail transportation in this country and to gain a better understanding of the problems to be solved. Both were realized to a certain

extent and it is the intention of the committee to continue the plan of getting the railway operating men to cooperate with us in this way.

The principal afternoon speaker was Mr. L. G. Coleman, Assistant General Manager of the Boston & Maine Railway, who gave an excellent paper in which he painted a graphic picture of the steam locomotive, its virtues and limitations. A number of other operating men joined in the discussion and contributed largely to the success of the meeting.

The past year has been distinctly one of progress in the field of the electric railway. No particularly spectacular events have been noted but there is a steady development going on in all lines which promises to handle the transportation problem most satisfactorily when it is finally presented.

Several new types of locomotives have been developed in the past year and improvements have been made in line construction, current collection, distribution systems, etc. Indications are that several large electrification projects will be started as soon as the financial situation will permit the railroads to undertake such improvements.

It is recommended for next year that:

1. Suitable papers be presented covering the points brought out in the Philadelphia meeting.
2. A suitable paper covering the subject of power supply for electric railways.
3. Papers covering the latest developments in electric locomotives.
4. Papers covering the development of the oil-electric or steam-electric locomotive.

N. W. Storer,
Chairman.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

IMPROVEMENTS IN STAGE LIGHTING CONTROL EQUIPMENT

The application of light—intricate in its many colors and intensities—to the plot of a theatrical production has, within recent years, been developed into a veritable art. The "light plot" of a large production is just as surely an essential factor in its success as are the actions and movements of the actors themselves. The proper use of light on the stage may transform a bare set of draperies into almost any scenic illusion desired. On the other hand a scene may be ruined as easily by improper lighting as by poor acting.

An example of the control equipment necessary in effectively bringing forth the grace and beauty of a play is illustrated in the new Scottish Rite Cathedral in St. Louis. According to the September issue of the *Electragist* (New York) a total of 600 kw. is distributed equally between the stage, auditorium, and the other parts of this new building. In this theatre, colored lights, from the borders, footlights, spot or floodlights may be used in any possible combination, which can be pre-selected after the light rehearsal and thrown on by a single lever at the proper moment during the play. This is done through the utilization of one of three program switches, each of which has 48 contact points. Each of these points is connected to the operating coil of a remote control switch and the selection of points is accomplished by the use of a fiber card with holes punched in it corresponding to the desired contact points in a given combination.

The three program switches are connected in parallel so that a practically unlimited number of setups can be obtained in a very short time, provided the desired fiber cards have been prepared in advance. It is also possible to add additional groups of lights to the set-up by individual manually controlled switches. All remote control switches are of the magnetically held type and by means of a momentary contact lock push switch on the pilot board, the entire system can be locked against interference when not in use.

A very unique feature of this installation is the method of dimming. For this purpose a choke coil, wound about a core of sheet-steel punchings, is placed in series with the lamps to be dimmed, and the current in a direct-current winding on the core varies the point of operation on the saturation curve of the core in such a manner that when the coil is open the "choking" effect is a maximum, and the lamps are operating on a voltage which is insufficient to furnish any appreciable amount of light. While on the other hand, when the full voltage of 110 volts is applied to the d-c. coil, the saturation of the core is so high that the choking effect is decreased to such an extent that the lamps approach their normal brilliancy. An auto transformer is used to overcome the 10 per cent choking effect which cannot be entirely eliminated in the amplifier dimmer.

Eighty-one of these amplifier dimmers are used and they take approximately one ampere each of direct current for the larger ones and around three quarters of an ampere for the smaller ones. By this method an accurate method of control is secured in a relatively small space.

Even the most scientifically designed reflectors, lenses, and color screens all go for nought if the control equipment at the switchboard is inadequate or improperly managed. Such equipment as that mentioned above permits an ease of control by means of which lighting effects can be obtained which surpass in beauty and grace even the wildest dreams of previous years.

A new church has recently been dedicated in the famous shop district of Chicago. This churchly edifice is unique, indeed, for it is situated in the business and amusement center of the city. Its cross, 568 feet above the pavement, is the highest in the history of the world. It will be illuminated each night in the year.

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The Pacific Coast Convention

AFFORDED EARNEST DISCUSSION AND ENJOYABLE ENTERTAINMENT

Earnest technical work and delightful social features make the Fall Convention held in Pasadena, October 13-17, a memorable convention of the Institute. A registration of 363 was recorded consisting of visitors from all sections of the country. The technical program was a full one with many papers in some sessions but each session drew an unusually large attendance and held it until the end. The entertainment program was also thoroughly enjoyed.

A lavish hospitality welcomed all who attended the meeting. Automobiles were ready at the call of any who wanted to make visits, and many made use of the opportunity. Power plants, substations, points of interest, the nearby country, the missions and other spots were visited by many of the men and ladies each day.

The ladies were cordially entertained with rides, card parties, shopping trips and so on. Both golf and tennis were also offered for their enjoyment.

On Monday morning the convention was opened by an address by the Honorable H. W. Wadsworth, Chairman of the Board of Directors, City of Pasadena. Mr. Wadsworth welcomed the visitors to the city in a most cordial manner.

Pres. Farley Osgood then addressed the convention and during the course of his talk spoke of some of the major activities of the Institute, notably the continued growth of the Institute, the new type of District Convention which was attempted for the first time at Worcester in June, the employment service of the Institute and other matters. Executive Secretary F. L. Hutchinson also addressed the members on some of the features of Institute work.

The first technical session was opened with the presentation by Professor Harris J. Ryan of three papers produced by himself and his assistants at Stanford University. These papers were:

The Hysteresis Character of Corona Formation, Harris J. Ryan and H. H. Henline, Stanford University.

A High Voltage Wattmeter, P. C. Clark and C. E. Miller, Stanford University.

Power Measurements at High Voltages and Low Power Factors, J. S. Carroll, T. F. Peterson and G. R. Stray, Stanford University.

The session was adjourned and followed by a delightful luncheon which was held jointly with the Electric Club of Los Angeles. After the luncheon President Osgood delivered an address entitled *The Electric Industry—Its Place in Civilization.*

In the afternoon the session continued with presentation of two papers, namely: *Corona Losses from Large Cables*, J. C. Clark, Stanford University, and F. F. Evenson, Benson Lumber Co., and *Corona-Loss Tests on 202-Mile, 220-Kv. Transmission Line*, Roy Wilkins, Pacific Gas & Electric Co.

Very interesting discussion ensued on these five papers. Those taking part were as follows: F. W. Peek, Jr., R. W. Sorensen, A. W. Hillebrand, J. B. Whitehead, H. B. Smith, F. G. Baum, R. J. C. Wood, J. S. Carroll, J. P. Jollyman (read by J. Mini) and Roy Wilkins.

Monday evening a reception was held in honor of President Farley Osgood and Past-President Harris J. Ryan. In the receiving line besides President Osgood and Professor Ryan were Mrs. Osgood, Dr. and Mrs. J. B. Whitehead, Prof. H. B. Smith, Mr. and Mrs. F. L. Hutchinson, Prof. R. W. Sorensen, Mr. and Mrs. J. E. McDonald, Mr. and Mrs. C. A. Heinze, Mr. H. E. Bussey, Mrs. L. R. Burnham, Mr. L. P. Burnham and Mr. L. W. W. Morrow. The dance following the reception was heartily enjoyed.

Tuesday morning's session opened with four other papers on transmission phenomena. These were: *The Corona as Lightning Arrester*, J. B. Whitehead, Johns Hopkins University; *Corona-Losses between Wires at High Voltages*, C. Francis Harding, Purdue University; *Lightning and Other Transients on Transmission Lines*, F. W. Peek, Jr., General Electric Co., and *Lightning* by E. E. F. Creighton. Mr. Harding's and Mr. Creighton's papers were read by H. H. Henline in the absence of the authors.

Extended discussion followed these papers and this was contributed by F. W. Peek, Jr., J. B. Whitehead, H. T. Plumb, H. Michener, L. P. Ferris, E. R. Stauffacher, A. W. Hillebrand, J. S. Carroll and H. J. Ryan.

The next contribution was a composite paper on *Transmission at 220-Kv. on the Southern California Edison System.* The authors who presented this paper were H. Michener, E. R. Stauffacher, W. D. Shaw, C. B. Carlson, J. M. Gaylord and V. D. Elliott. Following this a paper on *Operating Features and Technical Problems Associated with Interconnected Systems*, by W. E. Mitchell, Alabama Power Co., was read by F. C. Weiss.

This group of papers was discussed by H. A. Barre, H. J. Ryan, Roy Wilkins, J. Mini, Jr., H. C. Sutton, D. I. Cone, J. A. Johnson and L. M. Klauber.

Tuesday evening the convention attended the presentation of a delightful motion picture in a most unique theatre.

On Wednesday morning the paper *Large Steam-Turbine Generators*, by W. J. Foster, E. H. Freiburghouse and M. A. Savage, General Electric Co., was presented and discussion was given by A. M. Rossman and C. M. Gilt.

Three other papers followed this, namely: *Heating of Large Aluminum Transmission Line Cables*, R. J. C. Wood, Southern California Edison Co.; *High-Voltage Line Insulation*, A. O.

Austin, Ohio Insulator Co. and *A New Type of High-Tension Insulator*, H. B. Smith, Worcester Polytechnic Institute. They were discussed by R. M. Rossman, R. J. C. Wood, F. W. Peek, Jr., F. G. Baum, E. M. Hewlett, A. W. Hillebrand, H. Michener, J. B. Whitehead, H. B. Smith and A. O. Austin.

Wednesday afternoon the members were the guests of the California Institute of Technology, where a group of papers on physics was presented. These papers were as follows: *Influence of Temperature on Photo-Electric Emission*, R. C. Burt; *Collisions of the Second Kind*, Stanislaw Loria; *Electric Currents Due to Fields Alone*, S. S. MacKeown; *Electronic Orbits in Atoms*, R. A. Millikan and I. S. Bowen; *Transfer of Radiant Energy to Free Electrons*, E. C. Watson; *Electronic Emission under the Bombardment of Positive Ions*, A. L. Klein; *A Magnetic Lens*, W. R. Smith; *A Complex Quantity Slide Rule*, J. W. M. Du Mond and *A Method of Obtaining Steady High-Voltage Direct Current from a Thermionic Rectifier without a Filter*, F. W. Maxstadt.

Prof. R. W. Sorensen then explained the development and characteristics of the one million-volt cascade transformer which has been installed in the laboratory of the California Institute of Technology, after which a demonstration of the transformer was given, including a flashover test of Professor Smith's new type of insulator.

The laboratories at the Institute were open during the afternoon and the visitors enjoyed a number of tests and experiments which were performed for their benefit.

After enjoying a supper at the college, the visitors gathered to hear a lecture entitled *Fiction* by Dr. R. S. Millikan. Dr. Millikan explained some of the late researches into the structure of the atom and the nature of matter.

Thursday's session consisted of a number of papers on the application of electric power to various industries. The first paper, *Electrical Applications to Irrigation Pumping*, R. H. Cates, Southern California Edison Company, was presented and followed by discussion from L. J. Moore and Ralph Bennett. J. L. Wright presented his paper *Electric Power Application in Fir Mills*, followed by the paper *Electricity in Mines*, by F. L. Stone, G. B. Rosenblatt discussed both these papers. The paper *Contribution of Electricity to the Steel Industry*, K. A. Pauly, General Electric Co., was given and a discussion by G. E. Stoltz was read by Ralph Bennett.

J. L. M. Yardley then presented a paper by himself, *Electrometallurgical Applications*, and another paper *Electrical Equipment of Consolidated Mining and Smelting Company's Zinc Plant*, by R. H. N. Lockyer, and C. J. Russell closed the discussion for the afternoon.

During the day a large number of the guests took a trip up Mount Wilson where they visited the observatory and had an opportunity to inspect the marvelous scientific apparatus of the Carnegie Institute. Many remained all night on the mountain.

On Friday morning three papers on telephony were read, these being: *Telephone Transmission Maintenance Practises*, W. H. Harden, American Telephone & Telegraph Co.; *Determination of Magnitude and Location of Telephone Circuit Unbalances*, L. P. Ferris and R. G. McCurdy, American Telephone & Telegraph Co.; and *Guided and Radiated Energy in Wire Transmission*, J. R. Carson, American Telephone & Telegraph Co.

The participants in the interesting discussion which followed were D. I. Cone, J. E. Woodbridge, H. W. Hitchcock, V. D. Elliott, R. B. Ashbrook, R. G. McCurdy, L. P. Ferris and President Osgood.

A paper on *Street Lighting* by R. D. Whitney was the last on the program and the technical sessions closed with discussions by C. J. Stahl and L. P. Ferris.

Friday afternoon golf and tennis tournaments were played at nearby clubs. The John B. Fisken Cup for the highest net score in golf was won by K. E. Van Kuran who received also a handsome cigarette case. J. C. Jones won a silver cup for the next highest score. Mrs. H. H. Fogwell won the ladies' putting contest. The first prize for the tennis tournament, a silver cup, was won by O. F. Johnson. In the sweepstakes golf contest, first prize, consisting of two clubs, was won by W. C. Lynch. Others who won a prize of one club each were H. E. Summers, E. W. Freddell, W. C. Smith and A. W. Copley.

On the last evening, Friday, a happy ending was enjoyed in the form of a banquet which was followed by dancing. The banquet was presided over by toastmaster S. G. McMeen, and some interesting talks were given by a number of the more prominent guests. These included George E. Decker, Samuel Hinds, O. H. Ensign, C. W. Kliner, E. F. Scattergood, Dr. J. B. Whitehead, H. T. Plumb, C. E. Skinner, H. A. Barre and President Osgood.

The convention committee responsible for the delightful meeting consisted of an executive group as follows: R. W. Sorensen, Pasadena, Chairman; O. G. Johnson, Los Angeles, secretary; B. O. Bolster, Los Angeles; E. E. F. Creighton, Schenectady; H. B. Dwight, Denver; E. R. Hannibal, Spokane; C. R. Higson, Salt Lake City; W. C. Heston, San Francisco; C. W. Koiner, Pasadena; J. A. Koontz, Jr., Palo Alto; C. A. Lund, Tacoma; F. W. MacNeill, Vancouver; S. G. McMeen, Pasadena; L. W. Morrow, New York; E. E. Pearson, Portland; E. R. Stauffacher, Los Angeles.

This committee was assisted by the following gentlemen, who gave most freely of their time and effort to make all happy: J. N. Kelman, Los Angeles, Herbert H. Cox, Los Angeles, transportation committee; H. A. Barre, Los Angeles, finance committee; E. L. Bettannier, Pasadena, registration committee; George A. Damon, Pasadena, movie committee; R. Hopkins, Pasadena, publicity committee; Carl A. Heinze, Los Angeles, reception committee; J. E. McDonald, Los Angeles, paper committee; R. H. Manahan, Los Angeles, dance committee: C. G. Pyle, Los Angeles, entertainment committee; E. R. Northmore, Los Angeles, Mount Wilson trip; K. E. Van Kuran, Los Angeles, banquet committee; A. B. Wollaber, Pasadena, hotel committee.

Eastern Delegation Enjoys Trip

The trip of twenty-six eastern delegates to the Pasadena convention is reported to have been a splendid success. At every stop on the way the party was met and entertained lavishly and its path made easy to visit points of interest. The party gathered at Chicago and left on the evening of September 26th. Before its arrival in Colorado Springs the next morning it was greeted by Institute members from Colorado, some of whom had come by train or in cars over a hundred miles from Boulder and Denver. Those greeting the visitors were W. C. Du Vall, Boulder; R. B. Bonney, H. H. Kerr, B. C. J. Wheatlake and W. H. Bullock, Denver; Frank Vogler and M. Carroll, Colorado Springs.

These gentlemen convoyed the party to the Hotel Broadmoor and made arrangements for seeing the Cave of the Winds and the trip by automobile to the top of Pike's Peak. The Cave of the Winds was very interesting but the climax was the trip up Pike's Peak over a 36-mile road to an altitude of 14,100 ft. where a wonderful panorama was disclosed for a distance of a hundred miles in all directions. The altitude affected the whole party somewhat, but the exhileration induced by the view, the air and the hair pin turns on the road were sufficient to prevent mountain illness. Returning to the hotel, the party spent the evening quietly and was awakened early to view a wonderful sunrise and to take the train for Salt Lake City. The scenic beauty of the Royal Gorge and the Rockies along the Denver and Rio Grande were enjoyed immensely, and upon awakening the next morning the party found itself in the wonderful Salt Lake Valley. To its surprise and pleasure, H. T. Plumb and C. R. Higson met the train at Provo bearing gifts of fruit and the greetings of the Utah section. These gentlemen and others of their committee

were unstinted in their efforts to entertain the visitors and trips were made to wonderful colored canyons, the famous Bingham copper mine, the Mormon tabernacle and other points of interest in and near Salt Lake City. In the evening an informal dinner was held at which over seventy-five were present. H. T. Plumb acted as toastmaster and Dean Merrill welcomed the party to Salt Lake. Then Mr. Plumb demanded a little speech from all the visiting gentlemen and persuaded Mrs. J. L. McK. Yardley to give a delightful song which all enjoyed hugely, and a most pleasant and homelike atmosphere resulted.

Then the trip continued across the desert toward San Francisco. A late lunch and mile after mile of a dust-tossed desert having no vegetation gave new and interesting experiences and scenes to remember. The usual night in the berths was followed by a trip down Feather River Canyon and into the Sacramento Valley with its warm sunshine. Again a surprise awaited the party for at Stockton W. R. George, H. C. Heston and A. W. Copley boarded the train bearing greetings from San Francisco and boquets of beautiful flowers for the ladies. The trip across the bay and the cordial welcome received at the Palace Hotel were forerunners of a series of deightful experiences in San Francisco and vicinity. Shopping for the ladies under the guidance of Mrs. Johnson of the San Francisco Chamber of Commerce, while the men visited the Vaca-Dixon 220-kv. substation was followed by a united trip to Chinatown in the evening where the wonders of the shops, theatres and other Chinese features were viewed with interest and pleasure.

The next day was ideal. An early start was made in automobiles on a trip out along the Cliffs to the Presidio, the Golden Gate, Golden Gate Park and to the top of Twin Peaks and thence through a series of California cities to Palo Alto and Stanford University to see Prof. and Mrs. Ryan and their associates. A deightful reunion ensued and it was a very great pleasure and privilege to visit the home and workshop of the man who has done so much for the electrical art and who has endeared himself so greatly to all Institute members. Leaving these fine people and the pleasant surroundings at Stanford with reluctance, our party returned to San Francisco and prepared for its next move to Hetch Hetchy and the Yosemite Valley. The great hydroelectric and irrigation development at Hetch Hetchy awakened its wonder and admiration and a well worthwhile experience was recorded when the Yosemite Valley was reached that evening. The wonders of Yosemite Valley, the Big Trees and the view from Glacier Point entranced and delighted everyone and yet time was elapsing and the next stage called for a stop at Pasadena. Here permanent quarters were established easily and readily by reason of the host of welcoming committeemen who met the party at Glendale and escorted them to the Hotel Maryland. Here the ladies visited and rested while the men visited the 220-kv. Laguna Bell substation. But the next morning a cordial band of local committeemen and a fleet of automobiles awaited the guests to take them on a drive to San Diego, Tia Juana and other points south. This ride through orange groves, oil fields, glowing seaside towns and along the ocean reached a brief end at the old mission of San Juan Capistrano which the whole party visited with interest and pleasure. Then on the party went to partake of a splendid lunch at an ocean side resort and then on again to San Diego in its beautiful setting. Here some went on to Tia Juana and the joys of Mexico, while others visited the fortifications, Balboa Park and other points of interest near San Diego. But all united at Coronada Beach for a fine dinner and delightful evening with local Institute members. The return trip was made on an inland route the next day with a stop for dinner at unique and charming Mission Inn.

A. I. E. E. Delegates, Guests of Prof. H. J. Ryan, Stamford University, Cal., on October 4th

With one more day left a fitting climax to the trip was found in a cruise to Catalina Island where its wonderful subterranean gardens, its colony of seals and other interesting features were viewed with pleasure and then all returned to the Maryland Hotel with regret that au revoirs had to be said and work started. The convention was starting and the last sightseeing trip was over until another convention afforded an opportunity for a reunion.

Those taking the trip were Dr. and Mrs. J. B. Whitehead, Mr.

and Mrs. W. J. Foster, Mr. and Mrs. C. J. Russell, Miss Dorothy Russell, Mr. H. E. Bussey, Mr. and Mrs. J. T. Lawson, Mr. J. H. McGraw, Jr., Mr. and Mrs. Edgar Kobak, Mr. J. L. Burnham, Mr. L. W. W. Morrow, Mr. and Mrs. J. L. M. Yardley and Master Ralph Yardley, Mr. and Mrs. N. S. Amstutz, Mr. and Mrs. H. C. Sutton, Mr. and Mrs. J. C. Damon, Miss Alice Bassett and Mr. E. H. Hubert.

The thanks of the entire party were given Mr. Hubert for his able management of the trip and his indefatigable efforts to make everything smooth and comfortable. Not a hitch occurred from start to finish and all reported a wonderful time.

Future Section Meetings

Cincinnati

"Telephony." Joint meeting with Cincinnati Engineers' Club. November 20.

New York

The second meeting of the New York Section will be held in the Auditorium, Engineering Societies Building, 33 West 39th St., New York, on the evening of Wednesday, November 12, 1924. While it is not possible to definitely announce the program at the time of going to press, the subject will be on "Radio Broadcasting" and the speakers of national prominence. It is expected the Institute of Radio Engineers and the New York Electrical Society will participate in the meeting.

Pittsfield

"High Voltage Phenomena," by G. Faccioli, Chief Engineer, Pittsfield Works, General Electric Co., November 4.

"With MacMillan in the Artic," by Ralph T. Robinson, Chief Assistant Donald MacMillan. December 16.

Vancouver

Inspection trip to Ballantyne Pier and Government Grain Elevator. November 8.

"Skagit River Power Development," by C. F. Uhden. December 5.

100th Anniversary of Rensselaer Polytechnic Institute

On October 3-4 many notables from all over the world united to celebrate the One Hundredth Anniversary of the founding of the Rensselaer Polytechnic Institute at Troy, N. Y., the oldest technical school in the world.

Among the representatives of the engineering profession were: President Sir Charles Morgan of the Institution of Civil Engineers of Great Britain; John W. Lieb, representing the Institution of Electrical Engineers of Great Britain; President William Henry Patchell of the Institution of Mechanical Engineers of Great Britain; President Luigi Luiggi of the Society of Civil Engineers of Italy; Past-president Henri Abraham, Society of Electrical Engineers of France; President Arthur Surveyer, Engineering Institute of Canada; President Carl Ewald Grunsky, American Society of Civil Engineers; President Frederick Rollins Low, American Society of Mechanical Engineers; President William Kelly, American Institute of Mining and Metallurgical Engineers, and President Farley Osgood, American Institute of Electrical Engineers.

Herbert Hoover tendered the congratulations of President Coolidge and spoke on the contributions that the Rensselaer Institute had given to the engineering profession and to the world.

Dr. Frank P. Graves, State Commissioner of Education, James R. Angell, President of Yale University, Edward A. Birge, President of the University of Wisconsin, Samuel W. Stratton, President Massachusetts Institute of Technology; Dr. Albert A. Michelson, President National Academy of Sciences were also present.

The A. I. E. E. was represented by President Farley Osgood, Paul M. Lincoln and E. W. Rice, Jr. In extending the congratulations of the Institute, President Osgood spoke as follows:

On behalf of the American Institute of Electrical Engineers, and for its whole membership, I extend the heartiest congratulations to Rensselaer Polytechnic Institute in arriving at this, its one hundredth birthday.

We may well be proud of our first school of science, whose sons have made famous the world over, her teachings and fine traditions.

Rensselaer Alumni have raised many monuments to their Alma Mater in the form of master engineering and construction of every kind, and it has been with pride and satisfaction that the electrical engineers, with their more lately developed art, have assisted in its application in the more venerable branches of engineering as they have been developed during this long span of years at your Institute.

The roster of the American Institute of Electrical Engineers carries its share of Rensselaer Alumni, and surely none can forget your famous physicist, the late Henry A. Rowland, graduated in 1870, who endeared himself to electrical men in particular through his original work in the printing telegraph.

This is no time for me to recite even a small number of the many accomplishments of national and international note of your graduates, but it is fitting to record that the American Institute of Electrical Engineers realizes what exceptional work has been done by Rensselaer, as is evidenced by the lasting structures, enormous organizations, and original discoveries carried on by her fellows. From the little Rensselaer School to the beautiful far-reaching Institute of today, as we here see it, is a long look. An equally successful forward step of a century, and then another, and others to the Nth multiple, is the sincere wish of the American Institute of Electrical Engineers, which it is my specific duty and personal pleasure to record here today at this celebration of your Centennial.

President Palmer C. Ricketts spoke for the Rensselaer Institute and degrees were conferred as follows:

The honorary degree of Doctor of Engineering was conferred upon: Sir Charles L. Morgan, Dr. Henri Abraham, Dr. Luigi Luiggi, Arthur Surveyer, Dr. C. E. Grunsky, F. R. Low, William Kelly, and Farley Osgood; the degree of Doctor of Science upon Dr. Albert A. Michelson; and the honorary degree of Doctor Philosophy upon Dr. James R. Angell, Dr. Edward A. Birge, Dr. Samuel W. Stratton, and Dr. Livingston Farrand.

Engineering Societies Building Headquarters for Defense Day Activities

In a letter to Col. James L. Walsh of the New York District Ordnance Office, Army Building, New York, Secretary Alfred D. Flinn on behalf of the Board of Trustees extended to the Government the privilege of using the Engineering Societies Building as set forth in the following resolution:

"WHEREAS, on the first Defense Day, September 12, 1924, Engineering Societies Building, and particularly its assembly rooms, were found especially suitable for the activities of the New York District Ordnance Office of the War Department, and

"WHEREAS, it has been learned by informal inquiry that future similar use would be helpful to the Government,

"RESOLVED: that United Engineering Society, on behalf of its Founder Societies, tenders to the War Department for its New York District Ordnance Office the gratuitous use of the facilities of Engineering Societies Building as headquarters for annual Defense Day activities."

Northeastern District Awards First Paper Prize

At the meeting of the Executive Committee of the North Eastern District, held September 19, 1924, the First Paper Prize established by the Committee in March 1823 as outlined in the April 1923 Journal, was awarded to Professor H. M. Turner of Yale for his paper entitled *The Transient Visualizer*. Fifteen papers, including Prof. Turner's, were submitted in competition and the following received honorable mention: *Corona Investigation of an Artificial Line* by Murray F. Gardner and *An Efficient Tuned Radio Frequency Transformer* by F. H. Drake and G. H. Browning. The prize which consists of $25.00 cash and suitable certificate will be presented to Prof. Turner at the November 20, 1924 meeting of the Connecticut Section to be held in New Haven, Conn.

Engineering Foundation

ENDOWMENT INCREASED

By the will of Henry R. Towne, of Yale and Towne Manufacturing Company, who died October 16, the endowment of Engineering Foundation is increased $50,000. This sum is bequeathed to United Engineering Society as the trustee of the Engineering Foundation funds for the four national Societies of Civil, Mining, Mechanical and Electrical Engineers.

This bequest establishes the Henry R. Towne Engineering Fund, the income of which is to be expended by the Engineering Foundation Board for the purposes stated in its charter "the furtherance of research in science and in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind."

Mr. Towne was an engineer and manufacturer, a Past-President of the American Society of Mechanical Engineers, and active in its affairs. For many years he was a friend of Ambrose Swasey, the Founder of the Engineering Foundation. Like Mr. Swasey, he was a believer in the value of engineering research. This contribution to Engineering Foundation is a notable testimonial by a man of unusually wide and varied interests to the high importance of research to the engineering profession and the industries of our country.

ENGINEERING FOUNDATION OFFERS MEETING ROOM FACILITIES IN WASHINGTON

Engineering Foundation has been assigned Room 222 in the new building of the National Academy of Sciences and the National Research Council "in token of appreciation of the assistance rendered by the Engineering Foundation to the National Academy of Sciences in the establishment of the National Research Council."

The Academy building is at B and 21st Streets, Washington, D. C. near the Lincoln Memorial, and not far from the new War and Navy Buildings on B Street.

Room 222 is about 12 by 18 feet in floor area. It is furnished with a council table and twelve chairs and is suitable for committee meetings and small conferences. It adjoins Room 223 assigned to the Division of Engineering and Industrial Research, of the National Research Council.

Since Engineering Foundation will not use the room continuously, it has extended an invitation to the A. I. E. E. and other Societies to share the privileges of the room for purposes connected with researches and related activities. By this means the Foundation hopes to promote fellowship and cooperation between scientists and engineers.

Requests for the use of the room for committee meetings, conferences, etc., should be addressed to Engineering Foundation, 29 West 39th Street, New York, and should state purpose and time.

To individual members of the Societies are extended the privileges of the room for letter writing, for consulting the publications of the Foundation, and for other suitable purposes.

The National Academy of Sciences and the National Research Council have extended a cordial invitation to all members of the Founder Societies to visit the building and examine its scientific exhibits and library.

SOME WORK DONE BY ENGINEERING FOUNDATION A BRIEF RESUME

Engineering Foundation was founded in 1914, the first gift for endowment, $200,000, was delivered to United Engineering Society as trustee on February 24, 1915. Only the income could be expended. Members of the Foundation Board were elected March 25, 1915 and met for organizing April 15. With no expendable funds yet accumulated and less than $10,000 a year in prospect, no project could be undertaken immediately.

The great war was on. Within the year from the Foundation's first meeting, all indications pointed to the fact that the United States could not keep out. Scientific associations and engineering societies perceived the urgency for comprehensive organization. In June 1916, under leadership of the National Academy of Sciences and the Founder Engineering Societies, the National Research Council was created. No funds were in hand. Engineering Foundation met the emergency by proffering its income. It provided offices in Engineering Societies Building and engaged Dr. Cary T. Hutchinson as secretary. Its founder, Ambrose Swasey, and Vice-Chairman Edward Dean Adams, each contributed $5000 to supplement the income. With this aid, the Research Council was established and soon had funds from other sources. In 1919, when funds for endowment and a building were offered conditionally to the Academy and the Research Council, the two members of the Foundation just mentioned were among the contributors who made possible the purchase of the site near the Lincoln Memorial in Washington. From this beginning Engineering Foundation has cooperated continuously with National Research Council, especially its Division of Engineering and Industrial Research. This division occupies offices in Engineering Societies Building, New York, as guest of the Foundation, and the Foundation has been assigned a room in the new building of the Academy and the Council.

During the war, fatigue failures of airplane parts led to the study of the old problem of fatigue of metals. Funds for experimentation were not then forthcoming. In 1919, Engineering Foundation appropriated $30,000 for a two-year program prepared by the National Research Council to be carried out in cooperation with the University of Illinois. Industries became interested; the investigation is still in progress. General Electric Company, Allis-Chalmers Manufacturing Company, Western Electric Company and the Copper and Brass Research Association have contributed in cash $61,000, besides services and materials. Several other companies have supplied materials and services, as have also numerous engineers and scientists. Contributions of services, facilities and publications by the University for the past five years could not have been purchased tor less than $50,000. Valuable additions to knowledge and theory have been made. Other important investigations in this country and abroad have been stimulated.

With research committees of its Founder Societies, Engineering Foundation is cooperating in investigations of concrete and reinforced-concrete arches, steel columns for buildings and bridges, mining methods, rock-drill steels, properties of steam, bearing metals, lubrication, and strength of gears. Besides the Foundation's appropriations, totaling $15,000, contributions from industries and other sources aggregate more than $100,000.

In response to a request from engineers in the far West, the Arch Dam Investigation was organized. The States of California and Oregon, the U. S. Bureau of Reclamation, the City of San Francisco, several power companies, four universities and a number of engineers in this and other countries are cooperating. Under the leadership of Vice-President W. A. Brackenridge, of the Southern California Edison Company, a special fund of $100,000 is being raised for construction of a test dam 60 feet or more in height, upon which extensive experiments during and after construction will be performed. Subscriptions of the companies and the Foundation total to date

$50,000. Additional contributions are being solicited. Observations on existing dams and dams under construction are in progress.

Engineering Foundation joined with National Research Council in the world-wide Marine Piling Investigation, in establishing the Advisory Board on Highway Research and the American Bureau of Welding, and in compiling a directory of research laboratories in United States industries.

Personnel Research Federation has been created by collaboration of Engineering Foundation with National Research Council "for furtherance of research activities pertaining to personnel in industry, commerce, education and government wherever such researches are conducted in the spirit and with the methods of science." A group of gentlemen is now providing $100,000 for the support of this research organization for the next five years. This Federation publishes the *Journal of Personnel Research*, now in its third volume.

Engineering Foundation has been also a bureau of information. It has contributed to promotion of research by publications, publicity, correspondence, and participation in meetings of various organizations. Notable among its publications have been a Directory of Hydraulic Laboratories in the U. S. and the Research Narratives. Since January, 1921, the Narratives have been mailed in leaflet form to many men prominent in finance, industry, engineering and education, and reprinted in newspapers of this and other countries even as far away as Australia, and in technical and other periodicals all over America and as distant as China. The first fifty Narratives were recently republished as a book by Williams & Wilkins Company, Baltimore, and are being sold by it for the Foundation at the cost of publication and delivery, fifty cents a copy. The book is having a wide sale.

The latest annual report shows that the total income of the Foundation for 9 years, to December 31, 1923, was $169,600. Expenditures have been as follows:

Aid in establishing National Research Council	$10,500
Support of Division of Engineering and Industrial Research	26,000
Research projects	57,000
Promotion of research	17,200
Administrative expenses	24,300
Total expenditures	$135,000

There was accumulated for commitments and unforeseeable opportunities or emergencies, a reserve of $34,600.

During the past year, 190 leading engineers in 27 cities have accepted the invitation to serve as informal local representatives. They include one State governor, many past and present officers of the national and local societies, and executives of important corporations.

Mr. Swasey continues his keen interest in the Foundation and is a frequent visitor. Although his generous contributions, totaling half a million dollars, have not yet been supplemented, as is his earnest desire and that of the Founder Societies, intimation has been received of several intended legacies of unknown amounts. Effort is being made to increase this endowment so that larger work may be done. The Presidents and other representatives of the Founder Societies are aiding.

Many useful projects of the Societies and the Foundation await larger resources. Nevertheless, by using its funds to inspire and aid and supplement, the Foundation has accomplished cooperatively some noteworthy results. As it approaches the end of its first decade, the Foundation looks forward to a future of greater service with the united support of the profession, of the industries, and of individuals who have built fortunes upon engineering.

AMERICAN ENGINEERING COUNCIL

MEETING OF ADMINISTRATIVE BOARD OCTOBER 17th

At the meeting of the Administrative Board of the A. E. C. in Chicago, October 17th, the following resolution was adopted:

"Resolved, that the Committee on Government Reorganization as it relates to engineering matters of the American Engineering Council be instructed to adopt a policy of aggressively working for the complete project of the Department of Public Works as outlined several years ago."

This Committee will work with other organizations and submit a report at the next Assembly of the Council in Washington, January 16-17, 1925.

The subject of reclamation was discussed exhaustively and a resolution passed to carry out the recommendations of Executive Secretary L. W. Wallace, contained in a report which urges a complete study of this question in order to decide the proper course of the Council.

The Board voted its opposition to the Cramton Bill which seeks to take the control of industrial alcohol out of the hands of the Internal Revenue Commissioner and place it under the jurisdiction of the Prohibition Unit. This bill was thought to be very detrimental to the chemical industries and unnecessary to the enforcement of prohibition.

A resolution was passed to lay before the A. E. C. a protest against wooden Pullman sleeping cars; with the recommendation that it be brought before the Interstate Commerce Commission. This resolution is the result of the railroad accident on June 30 near Chicago, in which President Frederick W. Ives and other prominent engineers were fatally injured.

The Board also urged the appointment of engineer members to the Board of Tax Appeals; and adopted a report of its Patents Committee in regard to the passage of bills raising the salaries of the federal judges.

The report of the Coal Storage Committee, now available in published form was finally sanctioned. The Topeka Engineers Club was admitted to membership. A proposal to appoint a member of a committee of the American Construction Council to further better building was declined. The Board voted to invite the Founder and other national societies to cooperate in compiling an authoritative and comprehensive pamphlet on the compensation of engineers. A committee of from five to seven will be formed to direct the work.

A conference of secretaries of engineering societies will be held in Washington on the day preceding the annual meeting of the Assembly. A committee of five engineering society secretaries will be named to develop the program for the conference.

Action of the Executive Secretary in requesting engineering societies to consider the proposal to form a World Federation of Engineers was approved. This action was taken at the request of Dr. Sykora, President of the Engineers and Architects Association of Czechoslovakia.

A proposal that the Council withdraw from participation in the work of the National Board for Jurisdictional Awards was referred to a special committee. Reports of officers were approved, and much minor business transacted. The outlook for progressive development of the Council was described by President Hartness as encouraging.

Two joint meetings with the engineers of Chicago supplemented the Board's sessions. At a noonday meeting at the Auditorium Hotel, the speakers were President Hartness, Fred R. Low of New York, president of the American Society of Mechanical Engineers, and F. K. Copeland of Chicago, past-president of the Western Society of Engineers. Mr. Copeland appealed to the engineers of the West to support the Council. Mr. Low, in a striking speech, dwelt upon engineering activity in the public service, saying:

"The government does not run the country anyway. A change of policy on the part of any great industry would have a greater and more immediate effect upon our individual well being than anything that Congress is likely to do."

Capital and labor, industry and agriculture must cooperate if they would prevent a serious breakdown in the nation, Mr. Hartness told the gathering. He appealed to the engineers of the nation to take a hand in reconciling the conflicting groups.

Higher wages and shorter hours of labor, Mr. Hartness said, would be sure to result from the closer cooperation between the employer and worker, the farmer and the industrial groups of the big centers.

He urged that thrift be not penalized, and that exceptional skill, application and industry receive commensurate rewards.

"You cannot arbitrarily fix compensation for leadership," Mr. Hartness said, "and the unsound theories of communism would be disastrous to national development."

He asserted we are working twice too hard for the results we are getting. All the work that is being done in the world today could be done in half the time if "a high order of the spirit of team work" entered into all the walks of life.

Mr. Hartness thinks groups and blocs have come to stay in the United States, and, this being so, what the situation demands is not their elimination but their coordination.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute Headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the eliminaion of unnecessary expense for postage and clerical work.

1.—F. M. Bond, 621 W. Onondaga St., Syracuse, N. Y.
2.—C. E. Buchan, 1276 Eustis St., St. Paul, Minn.
3.—Harry S. Buchanan, 134 E. Ave. 54, Los Angeles, Calif.
4.—Jacob G. Feldman, Allied Electrical Co., Inc., Suite 3519, Grand Central Sta., New York, N. Y.
5.—C. H. Gauss, 2319 E. Fayette St., Baltimore, Md.
6.—Richard J. Grant, 107 E. South St., Pontiac, Ill.
7.—Frank W. Gross, 1135 W. 5th St., Santa Ana, Calif.
8.—Miguel Mesa Gutierrez, Bernardo Lopez 8, Jaen, Spain.
9.—T. J. Hodge, c/o Engineering Dept., Memphis Pr. & Lt. Co., Memphis, Tenn.
10.—George Janssen, The Roxana Petroleum Corp., Arkansas City, Ark.
11.—W. W. Johnson, 320 So. 19th Ave., East, Duluth, Minn.
12.—J. M. Kingsbury, 331 West 83rd St., New York, N. Y.
13.—George J. Lechner, The Edward-Johns Co., 1740 East 12th St., Cleveland, Ohio.
14.—E. R. McNee, 18 So. Seeley Ave., Chicago, Ill.
15.—E. M. Meyerend, New York Edison Co., 555 Tremont Ave., Bronx, New York, N. Y.
16.—Keith C. Millikin, Box 524, Midland, Ont., Can.
17.—Geo. W. Powell, Erection Dept., Allis Chalmers Mfg. Co., Milwaukee, Wis.
18.—Thomas F. Slatery, St. George Court, Stuyvesant & Wall St., St. George, Staten Island, N. Y.
19.—Max E. Sporn, 242 Penn St., Brooklyn, N. Y.
20.—John H. Spring, 5 York St., St. Catherines, Ont., Can.
21.—George T. Tavenner, Kern House, 2nd Floor, 36-38 Kingsway, London W. C., 2, England.

PERSONAL MENTION

Ward W. Lusk is at present with the Bethlehem Cuba Iron Mines Co., Santiago de Cuba, Cuba, Box 383.

George S. Alverson is now in the employ of Dwight P. Robinson and Company, Inc., 3708 Fifth Avenue, Pittsburgh, Pa.

Paul M. Conrad has become Assistant Electrical Superintendent of the Aluminum Company of America, at Alcoa, Tenn.

H. Hobart Porter has been elected to the Board of Trustees of Columbia University. Mr. Porter succeeds Dr. Walter B. James whose term has expired.

J. Aguado, having finished his work at the Pennsylvania State College, has accepted a position as Sales Engineer with the Armstrong Cork & Insulation Co., Pittsburgh, Pa.

Louis V. Sutton has resigned his position with theCarolina Power & Light Co. and is now Assistant General Manager of the Arkansas Central Power Co., Little Rock, Ark.

J. Simpson has resigned from the Central Technical School staff at Toronto to take charge of the Electrical Department of the London Technical School, London, Ontario.

George T. Smith is now engaged in electrical design work for Fairbanks Morse & Co., Indianapolis, Ind. He was formerly with the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

E. Blythe Stason has gone to Ann Arbor, Mich., to accept a professorship of law at the University of Michigan, at which institution he was formerly Assistant Professor of Electrical Engineering.

E. L. Milliken who was Assistant Manager of the Blackstone Valley Gas & Electric Co., Woonsocket, R. I., has accepted a position as Treasurer and General Manager of The Belamose Corporation, Rocky Hill, Conn.

John K. Keers is now Assistant Valuation Engineer of the New York Edison Co., Irving Place and 15th St., New York City. Mr. Keers was formerly connected with McClellan & Junkersfeld, Inc., of Brooklyn, N. Y.

Robert H. Gaither has just returned from an eighteen months' trip through the Orient, reporting on business conditions in India, China and Japan for the Whitin Machine Works, Whitinsville, Mass. His present address is 55 Pineapple Street, Brooklyn, N. Y.

J. C. Clark has left the Electrical Engineering Department of Stanford University and has accepted a professorship in the same department of the Iowa State College, where he will direct the work of graduate students and conduct research.

Fulton Cutting and Bowden Washington, for the past ten years executives of Cutting & Washington Radio Corp. and during the past three years in charge of engineering work for the Independent Wireless Telegraph Co., have organized the Colonial Radio Corp., 342 Madison Ave., New York City. They will manufacture broadcasting receivers.

J. Andrew Douglas has been engaged for the present college session at the Alabama Polytechnic Institute, Auburn, Ala., to handle the classes in electrical engineering—telephone, street railway and technical reading. R. J. Cooper will have supervision of the laboratory section of this department, which has formerly been under the direction of W. W. Hill, who is going to Johns Hopkins University in Baltimore to engage in research and instruction work in the Electrical Department.

A. R. Nissar has been carrying on an investigation into the present world railway electrification schemes and has already covered several countries in Europe. He expects to close his American trip by the end of this year and proposes to spend about three months again in Europe, sailing from New York about the first week of January, 1925 to cover England, France, Switzerland, Germany, Holland and Italy. He

would be glad to hear from any member of the Institute who would like to join him on his three months' trip to Europe, for the sole purpose of investigating railway electrification. Any member interested in this subject should communicate with Mr. Nissar, 850 25th Street, Altoona, Pa.

Charles R. Speaker has resigned his position as Radio Engineer in charge at the Washington Navy Yard and has established an office in the Evening Star Building, Washington, D. C., for technical and sales representation of responsible manufacturers. Mr. Speaker has been appointed District Sales Manager of the Roller-Smith Company, manufacturers of electrical instruments and circuit breakers, and the Pacent Electric Company, manufacturers of radio parts. A short while prior to resigning his position with the Navy Department he was awarded the Secretary of the Navy's invention prize of $500 for certain improvements on battleships and submarines. He is the designer of the high power tube transmitter at the Arlington Radio Station whose "time tick" at 10:00 p. m. is no doubt familiar to every owner of a radio set.

Obituary

Mable Weil, physicist, died on June 9, 1924. Miss Weil received her A. B. degree from Barnard College in 1916 and her A. M. in 1917 from Columbia University. She was awarded the Curtis Graduate Scholarship in mathematics in 1916, and the following year the same scholarship in physics.

Miss Weil was especially interested in X-ray research work and had been employed in connection with electrical and optical precision apparatus. She was the author of several papers, a member of the American Physical Society, and an Associate of the Institute.

Frederick William Pastor died in Chicago on September 29, 1924 after an illness of a few days. He had been connected with the Diehl Mfg. Co. at their plant in Elizabeth, N. J. from 1917-1922, and as their representative in Chicago, from 1922-1924. Mr. Pastor became an Associate of the Institute in 1919.

Edward R. Gorman, Superintendent and Manager of the Groton Water and Electric Dept., Groton, Conn., and an Associate of the Institute, died on August 14, 1924. He had been connected formerly with J. G. White and Co., the B. and O. Railroad, and the Connecticut Company in charge of overhead construction work.

Patrick B. Delany, inventor of numerous electrical devices, died at his home in South Orange, N. J., on Sunday, October 19th. He was born in Killavilla, Kings County, Ireland, in 1845, and was educated in national and private schools in Ireland and parochial schools in Hartford, Conn.

Mr. Delany was responsible for many improvements in synchronous, multiplex and other systems of telegraphy, and electric cables, etc. He also perfected a device by which submerged metallic substances can be located. This resulted in the recovery for the British Government of $30,000,000 worth of gold bars sunk by the Germans during the World War, and also $300,000 worth of copper nine feet below the bed of New York Harbor.

The Elliott Cresson gold medal was twice awarded Mr. Delany and he was also the recipient of the John Scott legacy medal of the Frankling Institute.

He was one of the charter members of the A. I. E. E. having joined the Institute in 1884, and was transferred to the grade of Member in 1891.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES SEPTEMBER 1-30, 1924

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Applied Electricity for Practical Men.

By Arthur J. Rowland. 2nd edition. N. Y., McGraw-Hill Book Co., 1924. 443 pp., illus., diagrs., 8 x 5 in., cloth. $2.50.

A textbook intended for readers with but little acquaintance with mathematics and science, for men who expect to make direct application of the principles given them in the class room to their daily work with commercial circuits and machinery. It does not attempt to cover the whole field of electrical science but is written wholly from the point of view of one who puts up and operates electric circuits and apparatus. The author is Educational Director for the Milwaukee Electric Railway and Light Company.

Atmospharische Störungen in der Drahtlosen Nachrichtenübermittlung.

By A. Koerts. Berlin, M. Krayn, 1924. (Die hochfrequenztechnik in einzeldarstellungen, bd. 1) 151 pp., diagrs., tables, 10 x 7 in., paper. 10.—mk.

An investigation of the atmospheric disturbances that affect radio communication and of the extent to which they may be

overcome, particularly by methods which diminish their power in proportion to the signal waves emanating from the station. The freedom from disturbances of the various systems of sending now in use is examined, with special attention to the factors that determine freedom from interference. The study is a theoretical one, but was undertaken from the viewpoint of the practical radio engineer and in confined to those questions which appear important in practical application.

CALCULUS FOR ENGINEERS.

By Ewart S. Andrews and H. B. Heywood. 2nd edition. Lond., Scott, Greenwood & Son, 1924. (Broadway engineering handbooks, v. 13). 269 pp., diagrs., 8 x 5 in., cloth. $3.00. (Gift thru D. Van Nostrand Co., N. Y.)

This textbook, the outcome of the combined efforts of an engineer and a mathematician, is an endeavor to present a course of study which will equip an engineer with a satisfactory knowledge of the subject. Engineering calculus is treated as a subject of engineering; and each new development is approached through an engineering problem. Much consideration is given to typical engineering applications.

CHEMICAL ENGINEERING CATALOG, 1924. 9th edition, N. Y., Chemical Catalog Co., 1924. 1082 pp., illus., 12 x 9 in. fabrikoid. $10.00.

The Catalog is a compilation of catalog data, condensed and standardized in size, covering the equipment and materials used in such manufactures as sugar, fertilizers, cement, paints and varnishes, foods, leather, glass, metals, oils, textiles, etc.; in fact, all the lines in which chemical processes are employed. This data is supplemented by an exhaustive index, which makes it possible to ascertain by whom any required article is sold.

The book is prepared under the supervision of a committee representing the American Chemical Society, the American Institute of Chemical Engineers and the American Section of the Society of Chemical Industry. In addition to the directory of materials a list of over 1300 technical books is given.

DICTIONARY OF ELECTRICAL TERMS.

By S. R. Roget. Lond. & N. Y., Isaac Pitman & Sons, 1924. 296 pp., 7 x 5 in., cloth. $2.25.

In preparing this dictionary the compiler has endeavored to steer a middle course between incompleteness and a redundancy which would make the volumn inconveniently large. The subject-matter has therefore been confined strictly to the meanings of words as electrical terms, omitting meanings that relate to neighboring sciences, to the terms used by practical men, omitting those of interest only to those engaged in research. The field covered embraces electric light, power and traction, telegraphy and telephony, including wireless, and other miscellaneous applications, as well as electricity and magnetism in general. The result is a compact volume, small enough for easy handling, which gives concise, intelligible definitions for between five and six thousand terms.

DIESEL AND OIL ENGINEERING HAND BOOK....LAND AND MARINE.

By Julius Rosbloom. 2nd edition, enl. Los Angeles, Calif., Technical Publishing Co., 1924. 780 pp., illus., diagrs., tables, 7 x 5 in., fabrikoid. $5.00.

Contains much information on the construction of land and marine types of Diesel and oil engines, on their operation and on maintenance. The various commercial types are described in some detail. The final chapter has only slight connection with the others. It is devoted to oil well machinery and to well drilling, pipe lines, etc.

ELECTRIC RAILWAY HANDBOOK.

By Albert S. Richey. 2nd edition. N. Y., McGraw-Hill Book Co., 1924. 798 pp., diagrs., 7 x 4 in., fabrikoid. $4.00.

This book brings together in convenient compass, data on subjects that are constantly coming up for consideration by operating, constructing and designing engineers in everyday practise. Roadbed, track, car houses, shops, train movement, motors, controlling apparatus, current collectors, trucks, braking, cars, transmission, distribution, signals and communications are considered, the essential information being given without attempting to cover in detail all the ramifications of electric railway engineering into other branches of the profession. The non-technical manager and operator, as well as the engineer, should find the book useful.

This edition has been revised and partially rewritten to include the many changes in practise that have occurred since the original publication of the book.

ELECTRICAL MACHINERY AND CONTROL DIAGRAMS.

By Terrell Croft. N. Y., McGraw-Hill Book Co., 1924. 305 pp., diagrs., 8 x 5 in., cloth. $3.00.

A collection of over five hundred circuit diagrams, which covers in general all of the apparatus used in modern electric power practise. The connections range from those for very simple motor circuits up to those for super-power stations. Diagrams are given for generators, transformers, synchronous converters. motor-generators, motors and control apparatus, and instruments

ELECTRICAL MEASUREMENTS IN THEORY AND APPLICATION.

By Arthur W. Smith. 2nd edition. N. Y., McGraw-Hill Book Co., 1924. 338 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.00.

A revision and enlargement of the "Principles of Electrical Measurements," written for those with some knowledge of physics, who wish further information regarding electrical and magnetic matters. It can be used as a laboratory manual, but it also treats amply of the principles involved and leads the student to reason out the facts. The electron theory is used throughout the book, electrical currents being considered as the flow of electrons along the circuit.

ELEMENTS OF COST ACCOUNTING.

By Anthony B. Manning. N. Y., McGraw-Hill Book Co., 1924. 166 pp., charts, 8 x 5 in., cloth. $2.00.

A textbook intended to supply a simple, yet complete presentation of the fundamental principles of cost accounting and its connection with the general accounting procedure. This is done by means of graphic charts with explanatory text and by a series of connected problems which are fairly representative of the practical work in the cost department of a manufactory.

ELEMENTS OF ELECTRICAL ENGINEERING.

By George D. Shepardson. N. Y., Macmillan Co., 1924. 335 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

An introductory textbook for technical schools and colleges, which contains in brief compass a discussion of the fundamental concepts and principles, and of the more important types of machines for both direct and alternating currents. An interesting feature is the lists of topics for further study appended to each chapter. These are chosen to send the student to other books and to train him to use electrical literature.

THE ENGINEER.

By John Hays Hammond. New edition. N. Y., Charles Scribner's Sons, 1924. (Vocational series). 218 pp., 7 x 4 in., cloth. $1.00.

The series in which this book appears is intended to assist the youth in choosing a profession. Drawing on his wide experience, Mr. Hammond explains what an engineer has to do, the advantages and disadvantages that the career offers, the training that the engineer should have, and the various branches of the profession that may be selected.

GRAPHIC STATISTICS IN MANAGEMENT.

By William H. Smith. N. Y., McGraw-Hill Book Co., 1924. 360 pp., diagrs., charts, 9 x 6 in., cloth. $4.00.

The author's aim has been to coordinate statistical practise and graphic usage in such a way as to give the business man a

presentation of the subject which will be understandable from his point of view. The subject is approached through a study of the principles of graphic practise. Next, the principles of statistical activity are discussed and, finally, both practises are considered as they apply to the different phases of business or to the individual business.

INTRODUCTION TO THE STROWGER SYSTEM OF AUTOMATIC, TELEPHONY.

By H. H. Harrison. Lond. & N. Y., Longmans, Green & Co., 1924. 146 pp., diagrs., 9 x 6 in., cloth. $2.50.

A text-book for students. Although it deals exclusively with one system of automatic telephony, the author believes that it will be useful as a general text, since the fundamentals of the art are generally the same in all systems. The book describes the Strowger system, as adopted for London, adequately, and is thoroughly illustrated by clear line cuts.

LEAD, THE PRECIOUS METAL.

By Orlando C. Harn. N. Y., The Century Co., 1924. 323 pp., illus., 8 x 6 in., cloth. $3.00.

An account of the occurrence of lead, of its metallurgy and of the manifold ways in which it is used in industry. The book is popular in style and readable, yet contrives to maintain a degree of accuracy and clearness which is noteworthy among works of its kind.

DIE LEGIERUNGEN IN IHRER ANWENDUNG FUR GEWERBLICHE ZWECKE.

By A. Ledebur. 6th edition, edited by O. Bauer. Berlin, M. Krayn, 1924. 424 pp., illus., diagrs., tables, 10 x 7 in., paper. 20.—mk.

This book is intended as a handbook for makers and users of alloys, who wish practical data on the properties of metals, the preparation of alloys and the composition and qualities of the metals and alloys of industrial importance. The greater portion of the book is devoted to such matters, but there is also an introductory section which summarizes the theory of metals and alloys.

PRINCIPLES AND PRACTISE OF ELECTRICAL ENGINEERING.

By Alexander Gray. 3rd edition revised by R. F. Chamberlain. N. Y., McGraw-Hill Book Co., 1924. 448 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

Originally prepared for the instruction of students of civil, mechanical and mining engineering, this text is suited for men who desire a broad idea of the principles and practise of electrical engineering and who have but a limited amount of time to spend on the subject. Fundamental principles are therefore discussed and the subject elaborated by emphasizing these principles rather than by solving mathematical equations.

Certain chapters have been revised for this edition and the text in general has been brought up to date.

RADIOTECHNIK, v. 1; Allgemeine Einfuhrung.

By J. Herrmann. Berlin u. Leipzig, Walter de Gruyter & Co., 1924. 128 pp., illus., diagrs., 6 x 4 in., boards. 1.25 g. m.

The first of a series of brief volumes on radio technology. It furnishes a concise survey of the present position of radio communication, telephonic and telegraphic. Special attention is given to the theoretical principles of the subject. Sending and receiving apparatus are described.

RELATIVITY FOR PHYSICS STUDENTS.

By G. B. Jeffrey. N. Y., E. P. Dutton & Co., [1924.] 151 pp., 8 x 5 in., cloth. $2.40.

The series of lectures here collected were delivered to students of physics at King's College, London. They are intended to introduce the Einstein theory to students of science who are able to make some use of mathematics as an instrument of thought but who may not be ready to face the mathematical analysis which is essential for the thorough exploration of the subject in all its ramifications.

SEASONAL OPERATION IN THE CONSTRUCTION INDUSTRIES.

By Committee of the President's Conference on Unemployment. N. Y., McGraw-Hill Book Co., 1924. 213 pp., charts, tables, 9 x 6 in., cloth. $2.50.

A feature of the work of the President's Conference on Unemployment which met in Washington in September 1921, was the attention directed to the wastes arising from seasonal and cyclical unemployment. Committees were appointed by Secretary Hoover to study certain of these matters, and the present report deals with the construction activities and the extent to which the dull season that characterize them may be eliminated.

The report presents the results of an extended investigation to ascertain the effects of climate on construction, the extent and nature of seasonal construction, the practicability of year-round construction and the remedies for seasonal construction. The conclusion of the committee is that custom, not climate, is mainly responsible for seasonal idleness. Recommendations are made to remedy this.

WARME UND WARMEWIRTSCHAFT DER KRAFT-UND FEUERUNGSANLAGEN IN DER INDUSTRIE.

By Wilhelm Tafel. Munich u. Berlin, R. Oldenbourg, 1924. 363 pp., diagrs., tables, 10 x 7 in., paper. $9.50.

Prepared with the needs in mind of students in technical colleges who expect to become operating engineers, factory chemists, etc., and thus to be interested in the generation of power and in industrial heating but not with questions of design. The book brings together the information on methods of heat utilization for power and heating, which is necessary for the proper selection and operation of prime movers and furnaces and for meeting the thermal needs of the factory as a whole. In the concluding section of the book the general principles are applied specifically to the problems of the iron and steel works and the paper-mill.

BOOK REVIEW

MARINE STRUCTURES, THEIR DETERIORATION AND PRESERVATION. Wm. G. Atwood and A. A. Johnson, October, 534 pp., 169. Fig. 14 Pl. National Research Council, New York. Price $10.00.

This book, which is a report of the Committee on Marine Piling Investigations of the National Research Council, is the first and only comprehensive and authoritative publication on this important subject which has appeared in the United States. The authors had unusual opportunities for securing the data used in its preparation. With the assistance and cooperation of the railways, several departments of the Federal Government, a number of the leading chemists and biologists of the United States, and a number of foreign organizations and individual scientists, they were able to make many tests and carry on a large number of experiments in the waters surrounding the North American continent and in the harbors of the Pacific and Carribean Islands and also to secure the results of many tests and inspections in foreign harbors.

It begins with a description of the organization of the work, of the tests and experiments made, and the methods used in making them, with a summary of the results obtained.

The biological section of the report contains descriptions of the commoner species of marine borers which were known to attack timber, stone or concrete, and includes reprints of several scientific papers prepared by the biologists cooperating with the committee, in which will be found descriptions of previously unidentified species of shipworms. Tabulations showing the distribution and the economic importance of the various species are also included.

Many timbers produced principally in the tropics have been considered immune from the attack of borers. Records of tests and service records of structures built with such timbers in all parts of the world are collected and analyzed and long time tests of the most promising of these timbers are listed.

There is a study of the various methods which have been used for the protection of timber and recommendations are made as to the conditions under which the use of each of these methods should be considered.

The chapter "Substitutes for Timber" contains service records and inspection reports for a large number of concrete and metal structures in all parts of the world. The conclusions drawn from these records depart somewhat from current engineering ideas and practise and will be found of great value to owners and engineers planning the construction of piers and wharves.

The Chemical Warfare Service of the Army submits a preliminary report of its investigations, which were planned to improve the methods and materials used for wood preservation.

The experiments made in each harbor are described in detail in the chapter on "Harbor Reports" as well as the inspection of structures in which practically all known materials were used. The boring animals found in each harbor are listed and in many cases the period of the year in which they are active. Recommendations are made as to the type of constructior which will probably prove the most durable under the various conditions.

There is a bibliography with about 2100 titles and a good index.

More Book Service

From time to time some member has occasion to consult a rather rare book or a foreign periodical that is not owned by many libraries. In most cases the need can be met by photoprinting the desired article, but there are cases where the length of the memoir makes this too expensive to be practical.

A new ruling by the Library Board will provide for many of these cases. It authorizes loans from the Engineering Societies Library of unusual reference works to public and college libraries, when needed by members of the Founder Societies, under the rules for inter-library loans of the American Library Association.

Applications for these loans should come from a library, not an individual. Loans will be made for a limited period and the borrowing library must assume the responsibility for the safe return of the book and the expenses.

The new policy makes the Library more available to members engaged in exhaustive research, and to those in need of treatises in foreign languages. It supplements the popular lending service that was inaugurated last winter to supply modern treatises, and fills a gap that photoprinting has not covered in the reference use of the collection.

The Library can now send the member at a distance an ordinary current text from its lending collection. It can send a reference book, if it is not available in his region or is not in too constant use to be spared. It can photoprint anything it has for him. It has provided the distant member with all the opportunities available to those in New York, so far as it is humanly possible.

Past Section and Branch Meetings

SECTION MEETINGS

Cincinnati

Some of the Main Features of the Heavens, by Professor Smith, University of Cincinnati. October 9. Attendance 62.

Detroit-Ann Arbor

The Development of Commercial Aviation, by Wm. B. Stout, President of the Stout Metal Airplane Company. A dinner preceded the meeting and short talks were given by Messrs. E. V. Sayles, E. T. Anderson and Professor J. H. Canon. September 30. Attendance 95.

Connecticut

Power Contracts on a Cost Basis, by Sidney Withington, New York, New Haven and Hartford Railroad. September 30. Attendance 50.

Fort Wayne

Report of the Investigating Committee on the Maumee River Dam Project, by J. J. Kline. The meeting was opened with moving pictures and a muscial program was furnished. Refreshments were served. September 25. Attendance 75.

Transients, by G. Faccioli, General Electric Company. The lecture was illustrated. October 8. Attendance 85.

Kansas City

The Kansas City Power & Light Company's New Supervisory Control System, by F. O. Jenkins.

General Electric Service Shop, by S. M. DeCamp.

Kansas City Power & Light Company's Research Laboratory and Its Relation to the Other Departments of the Company, by P. C. Ellis. A demonstration of the High Frequency Oscillator used in the Research Laboratory for testing insulators was given, and an inspection was made of this Laboratory and the General Electric Company's Service Shop. Refreshments were served. October 3. Attendance 25.

Lehigh Valley

The Electrical and Other Properties of Metals as Related to the Arrangement of Their Atoms, by Dr. L. W. McKeehan, Western Electric Co. September 25. Attendance 81.

New York

Politics and Power, by Guy E. Tripp, L. L. D., Chairman of the Board of the Westinghouse Elec. & Mfg. Co. In opening the meeting Chairman H. H. Barnes, presiding, called attention to the fact that the New York Section membership was about one-fifth the total membership of the Institute. In opening his talk, General Trip stated Superpower has three angles,—technical, economic, political. The technical problems have been solved; the economic advantages are admitted, thus narrowing the question to consideration from the political aspect. He touched upon the development of superpower, its effect on prosperity, the public interest in it, the unwarranted fear of exploitation, and finally the British view of superpower as outlined in a report drawn up by a committee under chairmanship of Lloyd George with its condemnation of public ownership.

Tendencies in Prime Mover Design, by Francis Hodgkinson, Chief Engineer, South Philadelphia Works, Westinghouse Elec. & Mfg. Co. Mr. Hodgkinson outlined the various developments in turbine design, both here and in Europe, touching upon cross compounding, end tightening, the large capacity high speed turbine, higher steam pressures, reheating, etc. October 15. Attendance 550.

Pittsburgh

Description of the Grant Street Substation of the Duquesne Light Company and Its Functioning with the Rest of the Power System, by E. C. Stone. Refreshments were served. September 9. Attendance 350.

Providence

Seeing and Working, Practical Side of Factory Lighting, by E. L. Elliott, Cooper Hewitt Electric Co. The speaker described the workings of the human eye and the methods of lighting best adapted for various kinds of work and for securing the highest efficiency from the workers. Joint meeting with the Power Section of the Providence Engineering Society. October 10. Attendance 35.

Rochester

Development of Automatic Sub-Stations, by T. F. Barton, General Electric Co. The lecture was accompanied by slides and a motion picture of one of these Sub-Stations in operation in Kansas City.

New Automatic Direct-Current Sub-Station, by E. K. Huntington, Rochester Gas and Electric Corp. An inspection trip was made to the Swan Street Sub-Station, where a demonstration was made of the automatic control operation of the machines. A buffet supper was served prior to the meeting. Joint meeting with Rochester Engineering Society. October 3. Attendance 165.

Seattle

Professor Kirsten, University of Washington, gave an interesting talk on his recent trip to Germany. Short talks of general interest were also made by Mr. Terrill and Mr. Harisberger. September 17. Attendance 53.

Toledo

Business Meeting. The following officers were elected for the present year: Chairman, P. R. Knapp; Vice-Chairman, A. W. Little; Secretary-Treasurer, Max Neuber; Chairman, Program Committee, A. W. Richardson; Chairman, Membership Committee, B. A. Harris; Executive Committee, A. H. Stebbins, Gilbert Southern and E. B. Featherstone. September 24. Attendance 18.

Toronto

Social Meeting. September 26. Attendance 115.

Vancouver

The Structure of Matter, by Dr. R. H. Clark. October 3. Attendance 25.

Worcester

Army Life with Mounted Troops in the Southwest and a Mexican Campaign, by Major Jerome W. Howe, U. S. Army, retired. Refreshments were served. September 25. Attendance 60.

Recent Practise in the Design and Operation of Electrically Heated Annealing Furnaces, by C. F. Cone, George J. Hagan Company. An inspection trip was also made to the Steel Treating Plant where these furnaces were inspected under normal operating conditions. Joint meeting with the American Society for Steel Treating. A dinner preceded the meeting. October 7. Attendance 117.

BRANCH MEETINGS

University of California

Inspection Trip to the U. S. S. Colorado. The trip was both interesting and instructive. September 20. Attendance 65.

The World Power Conference, by Robert Sibley. Joint meeting with other student engineering societies. September 24. Attendance 130.

Carnegie Institute of Technology

The Benefits of Belonging to the A. I. E. E., by E. C. Stone, Duquesne Light Co. A short talk was also given by Prof. B. C. Dennison. October 7. Attendance 55.

University of Denver

Business Meeting. The following officers were elected: Chairman, Carl C. Hersking; Vice-Chairman, Terryl Johnson; Secretary-Treasurer, Trevor R. Cuykendall; Membership Committee, Earl Reed, Charles Diller and Ray Hoover. September 26. Attendance 12.

Kansas State College

Economic Consideration of Power Factor Control of Long High-Voltage Transmission Lines, by C. W. Schemm, student.

Range Finding by Sound as Used in the United States Army, by W. E. McKibben, student. The following officers were elected: Chairman, R. B. McIlvain; Vice-Chairman, George Plank; Treasurer, H. R. Wege; Recording Secretary, N. R. Thomasson; Corresponding Secretary, G. J. McKimens; Executive Committee, S. H. Carter, September 22. Attendance 51.

Kansas University

The Relation of the Institute to Those Enrolled in the Electrical Engineering Department, by Professor Shaad. Refreshments were served. September 25. Attendance 100.

Lafayette College

Professor King read a paper reporting a trip of faculty members of the A. I. E. E. through works of the General Electric Company at Schenectady, N. Y., and at Pittsfield, Mass. The following officers were elected: President, John B. Powell; Secretary, Paul O. Farnham. September 27. Attendance 16.

A Summer's Work at the Hazelton Plant, by John B. Powell. October 4. Attendance 16.

Lehigh University

Difficulties in Telephone Testing, by L. C. Wurster, student.

Transformer Testing, by L. C. Wolcott. Talks on the benefits to be derived from the Society were given by Professors Estey, Seyfert, Schealer and Beaver. October 3. Attendance 80.

University of Michigan

Marvelous Advance of the Electrical Art Within the Last Fifty Years, by Professor B. F. Bailey. Asst. Dean George W. Patterson also gave a short talk to the Students. October 1. Attendance 100.

University of Nevada

Business Meeting. September 10. Attendance 15.

Accidents in the Electrical World, by F. O. Broli, Public Service Commission. October 8. Attendance 49.

University of North Carolina

Talks were given by Professors P. H. Daggett, J. E. Lear and E. G. Haefer on the Relation of the Students and Faculty in the E. E. School of the University and the Value of Cooperation between Them. October 2. Attendance 32.

Northeastern University

Methods of Generation, Transmission and Distribution of Power Used by the Edison Comapny, by Henry North, Boston Edison Electric Illuminating Co. The lecture was illustrated. The following officers were elected: Chairman, E. H. Barker; Assistant Secretary-Treasurer, H. F. Kingsbury. September 30. Attendance 33.

Notre Dame University

The Advantages to be Gained by Becoming Student Members of the American Institute of Electrical Engineers, by Dr. J. A. Caparo. The following officers were elected: President, McLeah A. Brule; Vice-President, Harold J. Kiley; Secretary, John A. Kelley, Jr.; Treasurer, Edward J. Pfister; Honorary President, Dr. J. A. Caparo. September 23. Attendance 30.

Ohio Northern University

Radio Transmission on Short Waves, by Hal Shaffer.

Benefits of the Branch to Students, by Professor Beyer. September 24. Attendance 45.

The Telephone Lineman, by Henry Ceslar.

A Modern Hydroelectric Station—by G. E. Thompson. October 8. Attendance 62.

University of Oklahoma

Business Meeting. The following officers were elected: President, Ralph Thornton; Vice-President, Chas. E. Bathe; Secretary, Floyd O. Bond; Treasurer, Ralph Tyler. Short talks on Student membership in the A. I. E. E. were given by Professors Tappan and Page. September 25. Attendance 22.

Purdue University

The New Electrical Building, and Its Meaning to Purdue, by Professor C. F. Harding.

The Advantages to be Gained from A. I. E. E. Membership, by Professor D. D. Ewing.

The A. I. E. E. from the Student Standpoint, and the Aim of the Organization, by Professor A. N. Topping. October 7. Attendance 211.

West Virginia University

Business Meeting. The following officers were elected: President, William W. Mountain; Vice-President, Maurice C. Holmes; Secretary, Joseph U. Neill; Treasurer, Edwin C. Jones. September 30. Attendance 22.

Research as Related to Patents and Patent Litigations, by G. E. Meintel.

A Novel A-C. Voltmeter, by M. Henderson.

What Edison Did During the War, by R. A. Osborne.

History of the Electric Light, by M. C. Holmes.

Lightning Arresters, by A. G. Kisner.

Industrial Electric Heating, by E. Gramm.

Super-Power and the Farmer, by C. H. Pike.

Testing of Electric Meters, by E. C. Jones.

Dielectric Strength of Insulation, by E. Pitzenberger.

The Steam-Electric Power Plant at South Kearny, N. J. October 8. Attendance 22.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

SALES REPRESENTATIVE, to call on engineers of power lighting, railway and industrial plants, renewal products. Location, Pittsburgh, Chicago and Western coast exclusive territory arrangement. R-4889.

MEN AVAILABLE

ENGINEER, industrial, B. S. in E. E., Assoc. A. I. E. E., age 30. Experience; two years with reputable consulting engineer, one year Western Electric Company, Hawthorne Works, Manufacturing Planning Division. Thoroughly capable in time study, manufacturing analysis and planning work. Available immediately. Location, Midwest preferred, others considered. A-1 references, salary $2200. B-8718.

TECHNICAL MAN, B. S., E. E. training; Assoc. A. I. E. E., twenty years' practical experience production and experimental work, familiar with handling help. Desires permanent connection of supervising or assistant executive nature with electrical or radio manufacturer. Married; location, greater New York. B-2798.

ELECTRICAL ENGINEER, graduate M. I. T. with post graduate study and research in electrical engineering. Two years' experience testing electric machinery, desires sales position where knowledge of electrical engineering is necessary. B-8414.

TECHNICAL GRADUATE, age 27. Seven years' practical experience on electrical construction and maintenance. Permanent connection with a growing, reliable concern desired. Associate A. I. E. E. and Western Society of Engineers. Available immediately. B-8761.

ELECTRICAL ENGINEER, technical graduate, age 25, desires to make connections with engineering firm, consulting engineers or architects. Experience as follows; two years with telephone company as plant engineer, one year testing and distribution experience, two years with public utility involving plant investigations and reports on operating problems, projects, etc. B-8759.

ELECTRICAL ENGINEER available. 1923 graduate from university abroad. One-half year test and two and one half years as construction engineer and designer of power plants and substations. Have been employed one year by large public utility company in East, but desire change to position offering opportunity for advancement. B-8781.

CHIEF ELECTRICIAN, twenty-two years' experience. Wishes position to take charge of electrical department in industrial plant; initiative and executive ability. Technical education, Assoc. Mem. A. I. E. E. Middle Eastern states preferred. B-8803.

ELECTRICAL MAINTENANCE ENGINEER, B. S. in E. E. 1921. Age 27, single. Two years operation and maintenance in a large power plant, and engineering connected with high tension transmission lines. One year in charge as instructor in electrical repair shop. Can handle men. West preferred. Available on reasonable notice. B-8444.

ELECTRICAL ENGINEERING GRADUATE, age 31, single. Nine years' experience in electrical engineering work. Industrial lighting, power installations, and central stations. Experience in designing, equipment, maintenance, plant, reports, testing and specifications. Desires position as assistant electrical engineer with good opportunities for advancement. Location, Connecticut and New York States preferred. Now available. B-8797.

GRADUATE ELECTRICAL ENGINEER, age 31, desires position with small manufacturer, where initiative and energy are demanded. Now managing a small electrical manufacturing business. Initial salary of minor importance, provided there is an opportunity for advancement. B-7798.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, eleven years' experience with railway light and power utilities. Experienced in the design and construction of power plants, substations, transmission lines and distribution systems. Desires similar connection with progressive public utilities. Engineer offices in Navy during the War. Age 33. Available on reasonable notice. A-4974.

ELECTRICAL ENGINEER, 26, graduate M. I. T. '22, B. S. degree. Two years' experience operation and maintenance high power radio station. Experienced Alexanderson Alternator, medium and low power vacuum tube transmitters, remote control systems, testing and installations. Desires change to design or research work. At present employed by large radio corporation. B-8831.

YOUNG ELECTRICAL ENGINEER, graduate class 1920, desires position. One and one-half years' testing experience with large corporation, two years' teaching experience; one year's experience estimating on power and light wiring. General knowledge along other subjects. Available on short notice. B-3781.

ELECTRICAL ENGINEER, age 30, college graduate, Westinghouse students training course, speaks foreign languages, seeks connection with an American export or manufacturing concern, preferably in electrical line. Have traveled extensively in Western Europe and in the Far East. Available at two weeks' notice. B-3993.

ELECTRICAL HEATING ENGINEER, technical graduate with wide experience in the successful application of electric heat. Responsible for a number of important developments, especially in the low and very high temperature field. Employed at present but looking for broader field. Salary $3600, married. B-8838.

CENTRAL AND SUBSTATION MAN, fourteen years with large modern systems. Acquainted with generating, converting, switch house and substation equipment of the heaviest types. Desires position as construction foreman or similar connection with public utility or contractor. Technical high school graduate and two years night engineering. B-8839.

YOUNG MAN, age 24, technical college graduate 1923 in E. E. Practical experience covers four years training in shop system and manufacturing methods, drafting room, layout and design of electrical instruments, specifications, production. Desires a start in any branch of E. E. New York Metropolitan locality preferable. B-6965.

FACTORY EXECUTIVE, electrical engineer, (M. I. T.), desires change in connections. Experience includes management of productive departments in large manufacturing company. Can institute methods and systems resulting in increased production and reduced unit cost. Reference obtainable from company employed by at present. B-8199.

EXECUTIVE ENGINEER, age 39, with broad experience on designs, construction and operation of power, substations and industrial plants, transmission and distribution systems, general lighting and power layouts. Desires a position with a reliable concern. Unquestionable references furnished as to executive ability. Member A. I. E. E. B-3954.

ELECTRICAL ENGINEER AND PHYSICIST, age 32, graduate and post-gradutae degrees from leading universities. At present assistant professor of electrical engineering and physics in large institution, desires to change position. Thorough knowledge of mathematical and experimental physics; specialist in radio communication. Responsible position in radio development desired. B-165.

GRADUATE ELECTRICAL ENGINEER, 35, desires position of responsibility with engineering firm, utility, or as representative of non-technical institution. Broad engineering and business experience as executive includes determination of designs for power plants, lines, factories, etc., selection of materials and equipment, construction, supervision, investigations of rates, development and financing. B-8237.

ELECTRICAL ENGINEER, technical graduate, age 30, married. Desires position as electrical construction superintendent or engineering executive. Seven years' practical experience. Employed at present, available one month. Prefer eastern location. Member A. I. E. E. B-8846.

DISTRIBUTION ENGINEER, technical with a number of years of practical experience in transmission work to 33,000 volts, sub and power stations. Distribution of direct and alternating feeders and net work, single, two and three phase, 2300-4150 and 6600 volt, as well as power distribution of 13,000 to 33,000 volts. Seeks interview with view of making a change. B-8847.

ELECTRICAL ENGINEER, technical graduate, wishes to connect with a live engineering organization. Twelve years' wide experience in electrical design, office and field, of power stations, substations, industrial buildings, with the largest engineering company. Have had responsible charge in field of appraisal of electrical properties. Associate A. I. E. E., N. E. L. A., holds state license. B-5393.

GRADUATE ELECTRICAL ENGINEER, 1924, age 21, desires start in electrical engineering so as to acquire experience. Available immediately. Vicinity of New York preferred. B-8792.

YOUNG ELECTRICAL ENGINEER, age 25, fifteen months' engineering and commercial experience, desires position with public utility company. Willing to work hard and learn your methods. Wants something permanent and with a future. University graduate, speaks two foreign languages. Associate A. I. E. E., American. Prefers town of about 10,000 population. B-7028.

WANTED TO represent manufacturers of high grade lines on the Pacific Coast, headquarters Seattle. Prefer central station and contractors lines; have practical and technical education; eight years' sales experience, can furnish best references. If you are looking for a live wire to handle your accounts let's get together. B-8853.

LEGAL AND ELECTRICAL GRADUATE, now employed in engineering department of radio concern, desires position in electrical field requiring ability to suggest improvement on, or examine novelty of original ideas. B-8848.

ENGINEER, E. E., M. E. Graduate work Ch. E. Served apprenticeship in foundry and machine shop and with manufacturer of electrical, also refrigerating equipment. Year development work. Five years responsible charge of design, construction and maintenance of plants. Short experience in sale of pumps and electrical machinery. Desires position with progressive organization. B-1738.

ELECTRICAL ENGINEER, versed also in mechanical, structural steel, concrete work. Power stations, transmission, etc., design, construction, operation. Practical, theoretical, reliable, responsible service. B-7337.

SALES ENGINEER, 30. fluent Spanish. Wide experience in Latin America in electrical construction and sales work. Desires position in export department, or as representative in Latin America. B-8860.

ELECTRICAL ENGINEER, technical graduate, age 33, married. Seven years' experience in design and installation of electrical equipment for steel rolling mills and in calculation and design of cascade regulating sets for steel mill motors, phase-advancers, etc., with large European manufacturing company. Desires position as designer or calculating engineer. B-8861.

MEMBER with twenty years' experience covering shop supervision, invention, development and design of motor control apparatus and five years as chief of engineering department, desires to make a change. Is seeking an executive position where past experience can be used and with prospect of advancement. Age 40, married. B-3061.

ELECTRICAL - MECHANICAL - INDUSTRIAL ENGINEER, technical graduate 1904. Two and one half years G. E. Test and engineering office experience, since in charge of construction, operation and maintenance of mechanical and electrical equipment in gold, silver, quicksilver and coal mines and reduction plants in States and Mexico. Familiar with foundry and shop practice. At present employed. B-8872.

ELECTRICAL ENGINEERING GRADUATE, about four years out of college, having had experience in testing, switchboard engineering, and designing of substations and power plants, desires responsible position with a reliable consulting engineering firm. Minimum salary $2400. Vicinity of New York preferred. Now available. B-8852.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1924.

Aker, W. A., Western Union Tel. Co., Atlanta, Ga.
Amezaga, M. F., The Francisco Sugar Co., Francisco, Prov. de Camaguey, Cuba
Antrack, H., R. Hoe & Co., New York, N. Y.
Barrington, F. H., Molony Electric Co., St. Louis, Mo.
Beers, H. W., H. W. Beers Electric Co., S. A., Mexico, D. F., Mex.
Biberman, L. S., General Electric Co., Schenectady, N. Y.
Booth, R. D., Jackson & Moreland, Boston, Mass.
Briefs, K., (Member), Electric Bond & Share Co., New York, N. Y.
Buenafe, M. M., Staten Island Edison Co., Staten Island, N. Y.
Carrington, E. L., Jr., Fafnir Bearing Co., New Britain, Conn.
Carswell, D. M., General Electric Co., Schenectady, N. Y.
Cipolletti, C. T., General Electric Co., Bloomfield, N. J.
Clarke, D. I., British Columbia Electric Railway Co., Vancouver, B. C.
Coffin, J. R., Jackson & Moreland, Boston, Mass.
Cummer, R. L., Canadian Line Materials, Ltd., Toronto, Ont., Can.
Danne, H. A., (Member), Electric Smelter & Machine Co., New York, N. Y.
Davis, C. C., Radio Corp. of America, New York, N. Y.
Deacon, H. L., Jr., Westinghouse Elec. & Mfg. Co., Boston, Mass.
Delehanty, J. E., General Electric Co., San Francisco, Calif.
Diffendaffer, J. S., Holtzschue Motor Co., Norman, Okla.
Ehrlich, M., New York Rapid Transit Corp., Brooklyn, N. Y.
Eldoen, S., West Penn Power Co., Freeport, Pa.
Fardoe, H. R., Moloney Electric Co. of Canada, Toronto, Ont., Can.
Finke, A. B., New York Edison Co., New York, N. Y.
Fischer, C. A., Dwight P. Robinson & Co., Inc., New York, N. Y.
Flynn, W. B., Day & Zimmerman, Philadelphia, Pa.
Frapwell, H. L., Research Corp., Bound Brook, N. J.
Fretz, J. C., General Electric Co., Schenectady, N. Y.
Garrett, P. B., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Ghioakes, A., Philadelphia Electric Co., Philadelphia, Pa.
Gill, P. C., British Columbia Electric Railway Co., Vancouver, B. C.
Good L., Jr., Union Electric Light & Power Co., St. Louis, Mo.
Hall, E. H., General Electric Co., Schenectady, N. Y.
Hammersley, T. L., Goodyear & Hammersley, Inc., New York, N. Y.
Hassan, B., Dodge's Telegraph & Radio Institute, Valparaiso, Ind.
Havenhill, M. A., General Electric Co., Schenectady, N. Y.
Holder, D. H., Jr., Oklahoma Gas & Electric Co., Drumright, Okla.
Holston, J. B., Wagner Electric Corp., St. Louis, Mo.
Holt, W. H., Hardwick & Magee Co., Philadelphia, Pa.
Hoover, P. L., Harvard Engineering School, Cambridge, Mass.
Jones, D. B., 131 25th St., Jackson Heights, N. Y.
Keeter, V. I., Southwestern Bell Tel. Co., St. Louis, Mo.
Kiess, R. T., Western Electric Co., Hawthorne, Ill.
Kramar, D. G., Great Western Power Co., San Francisco, Calif.
Lloyd, D. B., Jr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Lubinetzky, D. W., West Penn Power Co., New Kensington, Pa.
Lyon, F. D., (Fellow), Cahokia Power Plant, St. Louis, Mo.
Lyon, R., British Columbia Electric Ry. Co., Ltd., Vancouver, B. C.
MacLuckie, W. A., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Magley, A. J., Moloney Electric Co. of Canada, Ltd., Toronto, Ont., Can.
Martens, R. M., Thoner & Martens, Boston 16, Mass.
Marzan, M. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
McAllister, D. G., Westinghouse Elec. & Mfg. Co., Fresno, Calif.
Meserve, R. H., St. Paul Gas Light Co., St. Paul, Minn.
Morrone, A., 99 Montrose Ave., Brooklyn, N. Y.
Nordberg, E. E., Eastern Minnesota Power Co., Cambridge, Minn.
Northup, G. E., Scranton Electric Co., Scranton, Pa.
O'Bannon, S. P., General Electric Co., Schenectady, N. Y.
Parker, L. E., British Columbia Electric Co., Vancouver, B. C.
Parker, R. W., Sydney E. Junkins & Co., Ltd., Vancouver, B. C.
Peter, E., 159 West 74th St., New York, N. Y.
Porter, W. A., Public Service Co. of Colorado, Glenwood Springs, Colo.
Randall, H. A., Duquesne Light Co., Pittsburgh, Pa.
Rankin, C. S., University of Delaware, Newark, Del.
Rarick, J. C., Cleveland Electric Illuminating Co., Cleveland, Ohio
Russell, R. H., Detroit Edison Co., Detroit, Mich.
Sauter, M. H., General Electric Co., Pittsfield, Mass.

Sears, G. G., McGraw-Hill Co., Inc., St. Louis, Mo.
Shands, C. W., Western Electric Co., Inc., St. Louis, Mo.
Shepherd, B. V., Iowa Service Co., Missouri Valley, Iowa
Smith, C. R., American Tel. & Tel. Co., New York, N. Y.
Stark, I. A., Brooklyn Edison Co., Brooklyn, N. Y.
Stevens, C. H., 55 Hanson Place, Brooklyn, N. Y.
Stewart, A., British Columbia Electric Ry. Co., Ltd., Vancouver, B. C.
Sundar, P. M., Westinghouse Elec. & Mfg. Co., Detroit, Mich.
Timme, V. F., Tilden Technical High School, Chicago, Ill.
Tkach, J., Kohler Lighting Plants & Supplies, Jersey City, N. J.
Turner, V. L., Phoenix Utility Co., New Orleans, La.
Tyzzer, F. G., 175 Water St., Wakefield, Mass.
Ugalde, J. I., Mexican Light & Power Co., Mexico, D. F., Mex.
Upham, E. L., Barber-Colman Co., Rockford, Ill.
Valent, A. J., O. S. Leszay, New York, N. Y.
van Niekerk, A., Hotel Madison, New York, N. Y.
Vigliano, J., Electric Bond & Share Co., New York, N. Y.
Volckmann, E., Interborough Rapid Transit Co., New York, N. Y.
Waltz, W. W., Western Electric Co., Inc., Philadelphia, Pa.
Wyeth, F. H., Leeds & Northrup Co., Philadelphia, Pa.
Young, S. A., British Columbia Electric Railway Co., Vancouver, B. C.
Total 88

Foreign

Clarke, R. J., Electrica lEngineer & Contractor, Dublin, Ireland
Cox, W. R., General Electric Co., Ltd., Witton, Birmingham, Eng.
Kissel, F. T. M., Public Works Dept., Wellington, N. Z.
Smith, S. B., Marconi Wireless Telegraph Co., London, Eng.
Total 4

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held October 27, 1924, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Member

BROWN, CLAUDE C., Gas & Electric Engineer, California Railroad Commission, Los Angeles, Calif.
CAMPBELL, ALLAN B., Electrical Engineer, National Electric Light Association, New York, N. Y.
CONLEY, BROOKS L., Electrical Engineer, The Hoover Company, North Canton, Ohio
PARKER, KARR, Engineering Manager, McCarthy Brothers & Ford, Buffalo, N. Y.
ST. CLAIR, B. W., Engineer, Standardizing Laboratory, General Electric Co., West Lynn, Mass.

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A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons Ltd., 24 Bruce Road, Bombay—1, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

A. I. E. E. COMMITTEES

(A list of the personnel of Institute committees may be found in the October issue of the Journal.)

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Code of Principles of Professional Conduct, John W. Lieb
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Standards, H. S. Osborne
Edison Medal, Gano Dunn
Columbia University Scholarship, Francis Blossom
Award of Institute Prizes, L. W. W. Morrow

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Applications to Iron and Steel Production, F. B. Crosby
Production and Application of Light, G. H. Stickney
Applications to Marine Work, L. C. Brooks
Applications to Mining Work, F. L. Stone
General Power Applications, A. E. Waller
Power Generation, Vern E. Alden
Power Transmission and Distribution, Percy H. Thomas
Protective Devices, H. R. Woodrow
Research, John B. Whitehead

A. I. E. E. REPRESENTATION

(The Institute is represented on the following bodies; the names of the representatives may be found in the October issue of the Journal.)

American Association for the Advancement of Science, Council
American Bureau of Welding
American Committee on Electrolysis
American Engineering Council
American Engineering Standards Committee
Apparatus Makers and Users Committee
Board of Trustees, United Engineering Society
Charles A. Coffin Fellowship and Research Fund Committee
Engineering Foundation Board
John Fritz Medal Board of Award
Joint Conference Committee of Four Founder Societies
Library Boar , United Engineering Society
National Fire Protection Association, Electrical Committee
National Fire Waste Council
National Research Council, Engineering Division
Society for the Promotion of Engineering Education, Board of Investigation and Coordination
U. S. National Committee of the International Electrotechnical Commission
U. S. National Committee of the International Illumination Commission
Washington Award, Commission of
World's Congress of Engineers—1926, Board of Management

A. I. E. E. SECTIONS AND BRANCHES

See the October 1924 issue for the latest published list. The Institute now has 47 Sections and 77 Branches.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

A-C. Watthour Meters.—Bulletin 67, 32 pp. Describes Sangamo alternating-current watthour meters. Sangamo Electric Company, Springfield, Ill.

Resistor Units.—Bulletin 48,941A, 20 pp. Describes enameled resistor units suitable for general purpose applications. General Electric Company, Schenectady, N. Y.

Wiring Devices.—Catalog, 206 pp. Covers a comprehensive line of outlets, switches and fuses. The Bryant Electric Company, Bridgeport, Conn.

Power Transformers.—Bulletin 140, 16 pp. Describes Wagner power transformers and illustrates typical installations. Wagner Electric Corporation, St. Louis, Mo.

Mechanical Stokers.—Catalog E-5, 24 pp. Describes type "E" Underfeed Stokers. Combustion Engineering Corp., Broad Street, New York.

Pole Type Transformers.—Bulletin Ta 152, 8 pp. Describes Ferranti pole type transformers. Ferranti, Ltd., Hollinwood, Lancashire, England.

Electrical Steel.—Booklet, 56 pp. Describes the manufacture, and magnetic properties of iron and steel for electrical uses. The American Rolling Mill Company, Middletown, Ohio.

Motors.—Price sheets, specifications and instructions covering the Century line of squirrel cage induction polpyhase motors, 1/6 to 50 h. p., Century Electric Company, St. Louis, Mo.

Power Transformers.—Bulletin 2035, 24 pp. Describes Pittsburgh power transformers, single phase and polyphase, together with their accessories. Pittsburgh Transformer Company, Columbus & Preble Avenues, Pittsburgh, Pa.

Self-Starting Motors. Bulletin describes T R constant speed, polyphase, alternating current motors built in complete range of sizes from 3 to 125 h. p. in standard frequency, voltage and speed. The Triumph Electric Company, Cincinnati, Ohio.

Tapping Switches.—Bulletin Ta 173, 8 pp. Describes externally operated oil immersed tapping switches, the taps being changeable while the transformer is in position. Ferranti Ltd., Hollinwood, Lancashire, England.

Safety Switches.—Folder, 4 pp. Describes the "Bull Dog" safety switch in the new luminized finish. This finish is accomplished through an aluminum deposit process, and makes the switch instantly visible in the faintest light. Mutual Electric & Machine Company, 7610 Jos. Campau Ave., Detroit, Michigan.

British Engineering Directory.—A directory, 320 pp., containing the names, addresses and other details concerning British manufacturing engineers, and including practically every known manufacturer. Requests for the directory should be addressed to the Secretary, British Engineers' Association, 32 Victoria Street, Westminister, London, S. W. 1, England.

Electric Furnaces.—Catalog, describes the advantages, performances and results obtained from electric furnaces in the brass melting field. Detroit Electric Furnace Company, 2331 First National Bank Building, Detroit, Michigan.

Industrial Transformers.—Bulletin 1030, 4 pp. describes transformers specially built for various industrial purposes, including testing, resistance heating, furnace, industrial power, reactance coils for voltage control on electric furnaces and ozone transformers. American Transformer Company, 178 Emmet Street, Newark, N. J.

Metering Devices.—Catalog, 32 pp., "Modern Metering Methods." Describes the latest and most economical methods of installing metal meter devices, meter test switches, test blocks, laboratory meter testing devices and the necessary equipment and accessories for making installations. The Superior Switchboard & Devices Company, Canton, Ohio.

Testing Equipment.—Bulletin Ta 155, 6 pp., describes Ferranti oil testing equipment. The apparatus is a portable unit mounted on rollers, and can be used not only for ascertaining the insulating value of oil, but also for general experimental work, testing insulating materials, rubber gloves, switch gear, transformers, meters, generators, etc. Ferranti, Ltd., Hollinwood, Lancashire, England.

NOTES OF THE INDUSTRY

Payne Dean, Ltd.—The executive offices of the comapny have been removed from Stamford, Conn. to 52 Vanderbilt Avenue, New York.

Electric Machinery Mfg. Company, Minneapolis, Minn., has opened an office in St. Louis in charge of R. H. Olson. Mr. Olson was for several years sales engineer at the home office.

The Triumph Electric Company, Cincinnati, O.—The John F. Folkers Engineering Corp., Alabama, has been appointed to handle sales and service in the Mobile territory.

The Ward Leonard Electric Company, Mt. Vernon, N. Y., announce the appointment of the Dominion Engineering Agency, Ltd., D. M. Fraser, president, as sales representatives in Ontario. Mr. Fraser was for a number of years connected with the Canadian General Electric Company at Toronto.

G-E Quarterly Business.—Orders received by the General Electric Company for the three months ending September 30, totaled $58,389,832, as compared with $65,483,549 for the same quarter in 1923, a decrease of 11 per cent, according to a statement made by Gerard Swope, president. For the first nine months of the present year orders total $203,097,719 as compared with $229,747,304 for the same period in 1923, a decrease of 12 per cent.

The Rockbestos Products Corporation will open their own sales offices at 5942 Grand Central Terminal Building, 70 East 45th Street, New York, about the first of November. Harry B. Hammond will be in charge of the office as New York representative, and in addition to the metropolitan district, eastern New York State, New Jersey, Delaware, Maryland and eastern Pennsylvania will be covered. Mr. Hammond was formerly connected with the Westinghouse Electric & Manufacturing Company, and until recently was metropolitan sales manager for Johns Manville, Inc., New York.

New Current Transformers.—Current transformers designed for accurate metering where the secondary burden is high, have recently been placed on the market by the Sangamo Electric Company, Springfield, Ill. These transformers are known as types "F" and "G". Both types are rated at 50 volt-amperes and are built in capacities from 5 to 1000 amperes. The type "F" is intended for use on circuits not exceeding 7500 volts, 25 to 133 cycles, while type "G" is intended for use on circuits not exceeding 15,000 volts, 25 to 133 cycles. Both types are also built with two separate secondary circuits, one for meters and the other for relays and other auxiliary appliances.

Fuller-Lehigh Company, Fullerton, Pa., have entered into an agreement with Babcock & Wilcox, Ltd., London, to operate under the Fuller-Lehigh patents, whereby everything in connection with their pulverized coal equipment will be handled in the various countries throughout the world by Babcock & Wilcox, Ltd., of London, with the exception of the United States, its dependencies, Canada and Mexico. The modern manufacturing plants of Babcock & Wilcox, Ltd., in many parts of the world will enable these countries to save the duty and freight on the material, and thus makes it practical to instal the necessary equipment to use pulverized coal much more extensively. Since the agreement was concluded, Babcock & Wilcox, Ltd., have secured a number of contracts to equip boilers to operate with pulverized coal.